Journal
of
The Franklin Institute
Devoted to Science and the Mechanic Arts

Vol. 233 MARCH, 1942 No. 3

FRANKLIN'S POLITICAL JOURNALISM IN ENGLAND.*

BY

VERNER W. CRANE, Ph.D.,

University of Michigan.

It is now one hundred and sixty years since Benjamin Vaughan published in London the first collection of Franklin's writings to include political as well as scientific essays. It would be hard to imagine less likely circumstances for such an undertaking. The volume was compiled in the midst of the War of Independence. Franklin at the time was in Paris as the minister of the rebel Congress to the court of Louis XVI; in the past year his first great diplomatic triumph, the treaty of alliance, had brought France also into the war with Britain. Meanwhile, his editor was in England: a nominal enemy, but actually an ardent admirer and a friend of the American cause. Since 1777 a number of letters concerning the project had crossed the channel between author and editor. From Paris Franklin forwarded to the enemy capital in 1779 the "Addenda and Corrigenda" which gave special authority to the Vaughan edition. Vaughan reprinted not only Franklin's imperialist essays of 1754 to 1760, and certain of his anti-proprietary writings, but also—without apology to his English

* Delivered in the Hall of The Franklin Institute, December 1, 1939. This was one of the papers in the "Meet Dr. Franklin" Conference.

(Note—The Franklin Institute is not responsible for the statements and opinions advanced by contributors in the JOURNAL.)

public—such caustic satires on the policies of Lord North's ministry as the "RULES by which a GREAT EMPIRE may be reduced to a SMALL ONE," and "An Edict by the King of Prussia." In his preface, indeed, Vaughan confidently asserted of the man whom some Englishmen called "Old Traitor Franklin," that "history lies in wait for him, and the judgment of mankind balances already in his favor." "No man," he declared, "ever made larger or bolder guesses than Dr. Franklin from like materials in politics and philosophy, which, after the scrutiny of events and of fact, have been more completely verified."

So far at least as concerns Franklin's reputation of a political writer on the causes of the American Revolution, the judgment of history to which Vaughan appealed rests even today largely upon the essays which he managed to assemble in the sturdy octavo volume of *Political, Miscellaneous, and Philosophical Pieces*. Later editors from William Temple Franklin to Albert Henry Smyth greatly extended the corpus of Franklin's writings in other directions, notably through the publication of the major part of his magnificent correspondence. But of his numerous political essays on the great cause between the colonies and the mother country, written during the busy years of his London agencies and printed contemporaneously in newspapers and periodicals in England and America, the last Franklin editor added only about a dozen items to those collected so long ago by the admirable Benjamin Vaughan.

Thus it has happened that while biographers and historians have tasted the quality of Franklin's political writing, they have never appreciated its scope during the very years of his maturity both as a man of letters and a politician. They have missed seeing how largely political journalism absorbed his energy at crucial moments. Unaware of the extent to which his writings were printed and reprinted in the English and also the American press, they have underestimated his influence upon political attitudes on both sides of the Atlantic.

The complaisance of modern editors with their fragmentary collections of the Franklin essays on politics is the more surprising in view of the fact that both author and editor were highly dissatisfied with what Franklin called the

"very incompleat" edition of 1779. Vaughan had repeatedly urged Franklin to send him certain texts; but quite often he had been disappointed. The difficulty was that the two main sources from which they might have been furnished were inaccessible to Franklin in Paris. On his departure for France he had left his personal file of papers in Pennsylvania, in the keeping of Joseph Galloway, now a Tory. For many years, also, William Franklin had received from his father, as Benjamin later recalled, "sometimes the Rough Drafts, and sometimes the printed Pieces I wrote in London"; but the last royal governor of New Jersey was at this time in patriot custody in America. "If I should ever recover the Pieces that were in the Hands of my Son," Franklin wrote to Vaughan, "and those I left among my Papers in America, I think there may be enough to make three more such Volumes, of which a great part would be more interesting." In 1784 Franklin sought to enlist the aid of his son, now in England, for an enlarged second edition of Vaughan, but the project fell through.

Franklin's own testimony that he had written many more essays in England than Vaughan had been able to assemble, seemed sufficient warrant, several years since, for undertaking a search for new Franklin essays in the London newspapers. This was pursued both in the so-called evening papers of the type of the *London Chronicle*, which had been casually but not thoroughly inspected before, and especially in the extant files of the London daily newspapers, never hitherto explored by any Franklin student. Difficulties were encountered: many issues have disappeared; and Franklin, in common with the other controversial writers of the age, had usually assumed the disguise of anonymity or pseudonymity.

Happily he left more clues than his great contemporary and fellow-contributor in the 1770's to the *Public Advertiser*, the mysterious Junius. Among the clues which proved useful are drafts and memoranda in the great manuscript collections, especially in the American Philosophical Society; allusions by Franklin himself, or by his correspondents; a helpful list which Franklin drew up in 1769 of those essays of his which Goddard had reprinted in the *Pennsylvania Chronicle;* contemporary identifications by his journalistic antagonists, some of which

hit the mark, though others went far astray; his use of characteristic pseudonyms; and those other signs of authorship supplied by internal evidence, which in the case of so frugal a writer as Franklin are often highly convincing. Suffice it to say that it has been possible to recover what is probably the major portion of Franklin's political journalism in England; that this amounts in bulk to nearly the "three more such Volumes"—on the scale of the 1779 edition—which Franklin predicted; and that it is hoped that this belated "second edition" of Vaughan may shortly appear. Meanwhile the friends of Franklin may be interested in a brief analysis of the character and significance of this restored body of Franklin's political journalism, with sidelights upon Franklin's relations to the press.

As an old-time newspaper proprietor, trained in the rough-and-tumble of colonial politics, it is not surprising that Franklin began to send in letters to the London papers at least as early as 1758, and that he continued to write on imperial politics all through the English period, even during the stormy final year of his London residence. Long before, in his "Apology for Printers," he had observed: "That the Business of Printing has chiefly to do with Men's Opinions; most things that are printed tending to promote some, or oppose others." Here is as neat a description of propaganda as one is likely to find—framed, moreover, by a master practitioner. It seems likely, indeed, that little in modern propaganda would surprise Franklin, except the name! The art, he understood, was an ancient if not always an honorable one: the eighteenth century had, as usual, introduced improvements. "To the haranguers of the populace among the ancients," he wrote in 1767, "succeed among the moderns your writers of political pamphlets and news-papers, and your coffee-house talkers." In 1782 he pointed out the great advantage of modern means of persuasion over ancient oratory: "The facility, with which the same truths may be repeatedly enforced by placing them daily in different lights in *news-papers*, which are everywhere read, gives a great chance of establishing them. And we now find, that it is not only right to strike while the iron is hot, but that it may be very practicable to heat it by continually striking."

To heat the iron in the controversies between colonies and mother country, Franklin himself had recourse both to pamphleteering and newspaper writing, and also to coffee-house oratory. Of his contributions in the latter sort, more important in forming opinion in eighteenth-century London than anything comparable today, little has survived. The recently reprinted dialogue on slavery of 1770 may well be what it purports to be, the dressed-up version of a coffee-house debate. But in any case Franklin was a more persuasive writer than talker. Two unidentified Franklin pamphlets, of 1766 and 1768, have been recovered, and there are traces of two others which were written but apparently not published. It was in the newspaper, however, that Franklin found his real forum in England.

A forum for debate the newspaper of the eighteenth century was intended to be. Especially was this true of London. There three great dailies circulated, and half-a-dozen so-called evening papers, printed thrice a week, which were carried by the post to Bath and Bristol and the provincial towns generally; they had, besides, their regular subscribers in America. In addition to news, usually stale, from the continent and the kingdom and even from the colonies, and advertising and literary notices—but as yet no editorials—a principal department comprised essays, largely controversial, on a wide range of political topics, in the form of letters to the printer, usually signed with a pseudonym. These contributed letters had an importance in the formulation of opinion far beyond that of letters from readers of today. It was the repeatedly asserted policy of the printers to open their columns without discrimination to writers on either side of any current debate; and in the best English papers, to a greater degree it would seem than in the colonial gazettes, this policy of impartiality was actually maintained. Henry S. Woodfall proudly described his daily, the *Public Advertiser*, as a "cockpit for Political Spurring." He strongly repudiated charges of partisanship, as in 1774, when one correspondent asked how he and his colleagues could justify to their consciences "the constantly printing Essays and Paragraphs, which accuse the Bostonians of Rebellion." Only a few weeks later, however, another writer—no doubt a ministerial

hack—denounced the prostitution of the English press, under the guise of impartiality, to the cause of American Rebellion! On still another occasion Woodfall gave the following answer to a complaint: "The Printer does *not* plead guilty to the Charge of *Partiality*.—If twenty Gentlemen write Letters to answer One JUNIUS, the Printer inserts these Letters as quick as possible." It is obvious, however, that some among the score of anti-Junius scribes must wait upon the convenience of the printer. It was certainly an advantage, then, for a writer on political questions to have personal relations with the proprietors or shareholders of the principal papers. Such relations Benjamin Franklin amply enjoyed. It is therefore not surprising that only rarely do his letters appear to have been excluded: that commonly they were printed very promptly; and that often they were given special prominence. His newspaper connections are not far to seek. A good friend and neighbor in Craven Street was the wine-merchant Caleb Whitefoorde, himself a writer for the papers and also one of the proprietors of the *Public Advertiser*. But it was probably through his long-time printer friend, William Strahan, that Franklin first established his close connections with the London press. Strahan was not only the principal stockholder of the tri-weekly *London Chronicle*, with a one-ninth interest; he had important shares also in the *Public Advertiser*, the *Public Ledger* (another daily), and *Lloyd's Evening Post*. To each of these, as also to the third daily, the *Gazetteer*, Franklin was a contributor. Thirty-three of his essays have been discovered in the *Public Advertiser;* thirty-two in the *London Chronicle*, and eighteen in the *Gazetteer*.

By modern standards the circulation of these papers was absurdly small. The *Public Advertiser* is said to have printed about 3,000 copies; the *Gazetteer* in 1769 got out 5,000. But they were certainly read much more widely than these figures would indicate, especially in the coffee-houses where they were also hotly debated. The public opinion which they helped to form was that of a minority, but of an influential minority in a country controlled by a minority ruling class. It was especially when Parliament was in session that political letter writers sharpened their quills, and among the rest

Benjamin Franklin. It is significant of his purposes that most of his essays were printed in the months of the parliamentary sessions or of impending elections. Thus some twenty-four of his political pieces were printed in January issues of four years: 1766, 1768, 1769, 1770.

When letters caught on they were given wider currency through reprinting from the dailies into the evening papers—which also, as in the case of the *London Chronicle*, printed some essays for the first time—and in such monthly periodicals as the *Gentleman's Magazine*. This frequently happened with Franklin's essays; and indeed most of the texts presented by his editors have unfortunately been taken from these imperfect reprintings, or else from incomplete manuscript drafts. On this side the Atlantic, colonial printers to fill out their sheets culled letters as well as old news from London papers and periodicals. Franklin fared especially well in the colonial gazettes, although it was rare that his authorship was asserted, and then sometimes incorrectly. The notable instance in which he was identified to American readers occurred in 1767. To offset malicious partisan attacks upon the agent's conduct in the affair of the Stamp Act, William Goddard reprinted in the *Pennsylvania Chronicle* a whole batch of Franklin essays from London papers. With his keen journalistic sense, and his wide connections among American printers, it is likely that Franklin himself saw to it that papers containing his essays came their way. Certainly it is true that most of his English writings were currently reprinted at least once and often many times in America; a thorough canvass would probably greatly extend the evidence. He wrote, then, for an audience both in England and America. And he wrote most often in the dual rôle of an Englishman and an American, seeking in the midst of bitter disputes to promote a more enlightened imperialism.

It was, however, as an imperial expansionist, and an advocate of royal government in Pennsylvania, that Franklin first addressed English newspaper readers in those years of his earlier agency which were also the climatic years of the Seven Years' War. His first contribution was probably the letter signed "A.B." in the *London Chronicle* for September 19, 1758, which was recognized as his by Cecilius Calvert:

a piece of anti-proprietary propaganda in line with the original purpose of his agency.

But most of his journalism between 1758 and 1761 turned toward broader issues of the empire at war. When a peace movement arose in England—prematurely as it seemed to this expansionist American who hoped for great continental acquisitions from the French in North America—he addressed to Mr. Chronicle a series of letters which were frankly war propaganda. As "CHEARFUL" he demonstrated in December how the supply of twelve millions for the next year might be raised not once but several times over, by the exercise of Poor Richard's stock virtues of "industry and frugality." And so might Britain avoid "a peace which shall be either *unsafe* or dishonourable to the nation." As "A New Englandman" he turned aside in May, 1759, to defend the colonial soldiery against the slurs of British officers serving in America whose letters he had read with mounting indignation in the London papers. (From this time on the defense of the Americans became one of his self-appointed tasks in England: defense of their customs as well as their opinions, of their dietary even, as in his championing of American corn bread—a defense not so much against malignity, as against the dismaying ignorance of things American which he encountered in the mother country.) In November, 1759, he returned to his war propaganda to draw the portraits of those Englishmen who "wish for a peace with *France*, let the terms be ever so dishonourable, ever so disadvantageous . . . ;" as he did again in 1761, in the fictitious chapter "Of the Meanes of disposing the Enemie to Peace" which he alleged that he had drawn "from the famous Jesuit *Campanella's* discourses address'd to the King of *Spain*." Here he listed among the pacifists: "All those who be timorous by nature, amongst whom he reckoned men of learning that lead sedentarie lives, using little exercise of bodie, and thence obtaining but few and weake spirits." In 1767, however, he reconsidered the case of the intellectuals when he found some of them clamoring for the use of force in America. He then wrote for the same *London Chronicle* (April 9, 1767) a curiously similar passage but to exactly the opposite effect:

> It is remarkable that soldiers by profession, men truly and unquestionably brave, seldom advise war but in cases of extreme necessity. While mere rhetoricians, tongue-pads, and scribes, timid by nature, or from their little bodily exercise deficient in those spirits that give real courage, are ever bawling for war on the most trifling occasions, and seem the most bloodthirsty of mankind.

The climax of Franklin's political writing in the period of the first agency was, of course, the publication in April, 1760, of his famous Canada pamphlet, *The Interest of Great Britain*, arguing the case for a peace which should secure Canada and the trans-Appalachian West, rather than West Indian islands, for Great Britain. It is not so well known that Franklin had prepared the way for this pamphlet by printing in the *Chronicle* late in December, 1759, a letter signed "A.Z." which gave to certain arguments of the forthcoming tract a satirical turn.

When Franklin returned to England on his second Pennsylvania agency at the end of 1764, he returned to a land of many friendships and many useful connections—scientific, literary, and among others journalistic. Already he had his *entrée* to Strahan's *London Chronicle*. Soon he was contributing also to the daily papers, as the successive crises over the Stamp Act, the Townshend Acts, the Tea Act, and the rest gave occasion. During the second agency even more than during the first the anti-proprietary campaign took an insignificant place in his writings among the larger concerns of the colonies in the era of imperial reorganization.

Franklin's letters to the newspapers appeared over a bewildering variety of signatures. Smyth listed some eighteen pseudonyms, but the list can be extended to about forty. Franklin's practice was thus quite unlike that of Junius, who made one signature immortal; or that of his own uneasy and suspicious colleague from Virginia, Arthur Lee, who dreamed of a like immortality as Junius Americanus. Thus far there has turned up among the new materials only one considerable Franklin series of a definitely periodical character: The Colonist's Advocate papers, eleven in number, which appeared in the *Public Advertiser* between January 4 and March 2, 1770. They marked the climax of Franklin's drive in the press for the repeal of the Townshend duties. The partial

repeal by Parliament occurred March 5, and the series suddenly ended.

Better suited to Franklin's purposes in propaganda, as also to his temperament, was his more usual method of scattering a number of detached essays through the papers, over a variety of signatures, and in a great variety of modes. It would seem that he was deliberately seeking to create the impression that a numerous regiment of pro-American writers was in the field. If so, he was not altogether successful, for by 1774 ministerial paragraphers were tracing all such propaganda, sometimes quite erroneously, to what one of them called "Judas's office in Craven Street." Sometimes he chose to write in the character of an Englishman—several times over the actual signature of "A Briton." Franklin's methods reflect the *ad hoc* nature of much of his political writing in England. Most often the letters were answers to writers who, he conceived, had misstated American facts or misrepresented American views. "Angry reflections on the Americans" were pretty certain to draw his fire.

The winter of 1765–6 saw him at his busiest, by testimony of such intimates as Strahan and Dr. Fothergill. "He is forever with one Member of Parliament or other," wrote Strahan on January 11, describing his activities as a lobbyist for the repeal of the Stamp Act. "All this while too," Strahan continued, "he hath been throwing out Hints in the Public Papers, and giving Answers to such letters as have appeared in them, that required or deserved an Answer.—In this Manner is he now employed, and with very little Interruption, Night & Day." Strahan was not exaggerating. In the newspapers that winter Franklin had challenged each of the prominent Grenvillite writers in turn. To "Tom Hint" he had replied over his favorite signature of "F.B."; to "Pacificus" as "Pacificus Secundus"; to "Vindex Patriae" as "Homespun" or "N.N." Not a little of the fencing skill which he exhibited on the great occasion of his examination before the House of Commons in February may be traced to his practice in these preliminary bouts in the London press.

In later years Franklin continued to reply to current "misrepresentations," as he called them, of the Americans. Thus in March, 1767, he read in the *Gazetteer* a satirical paper

by some Grenvillite writer called "Right, Wrong, and Reasonable, according to American Ideas." In April he retorted in one of the most pungent of the newly discovered essays under this caption: "RIGHT, WRONG, and REASONABLE, with regard to America, according to the Ideas of the Gentle Shepherd, and the genuine meaning of the papers and pamphlets lately published by him and his associates." Though here he deliberately borrowed the form of discourse set by his antagonist, he managed greatly to improve upon it. This was unhappily not the fortune of Francis Bernard, former royal governor of Massachusetts, when he rashly attempted a reply in the same kind to one of the most brilliant of Franklin's political satires. At least Franklin himself had reason for believing that it was Bernard who wrote the "long labour'd, and special dull Answer" in the *Public Advertiser* to his own famous essay of September 11, 1773: "RULES by which a GREAT EMPIRE may be reduced to a SMALL ONE."

Franklin's political essays were timely, which is the essence of journalism; but his literary talent, and the wisdom which he managed to distill into even his slightest pieces, usually save them from being merely ephemeral. In his correspondence are passages which throw light on his careful timing of his press campaigns. Within ten days in April, 1767, he printed four considerable essays, three of them in two consecutive issues of the *London Chronicle*. In an unpublished letter to Joseph Galloway he confided the reasons for this special activity:

> I have written several Papers to abate a little if possible the Animosity stirr'd up against us, and flatter myself they may be attended with some Success. I have taken that Method to answer all the groundless Charges, and state aright all the mistaken Facts that I heard urged in the Debates at the House of Lords, thô I durst not mention those Debates. I send you some of them. They have been reprinted here in several of the Newspapers.

Again in August, 1768, he wrote, once more to Galloway:

> . . . a Party is now growing in our Favour, which I shall endeavour to increase and strengthen by every Effort of Tongue and Pen . . . .

From August to December, accordingly, he printed some ten essays, only half of which have been preserved in his collected writings.

Franklin's strong literary bent is revealed in the variety of forms which he employed in his political writings, as well as in the familiar felicities of his style. There are allegories, hoaxes, imaginary colloquies, the Socratic discourse, as well as straight-out argumentation. Some of these forms Franklin had practiced since his salad days in the Junto, and throughout his early writing for the Boston and Philadelphia papers. Elsewhere it has been shown that in a piece printed in 1770 Franklin was pretty surely recalling the method he had employed in the *Pennsylvania Gazette*, so far back as 1755, in his dialogue between X, Y, and Z in defense of the Pennsylvania militia act. For he began in very much the same form another dialogue, "A Conversation between an ENGLISHMAN, a SCOTCHMAN, and an AMERICAN, on the Subject of SLAVERY," which Woodfall printed in the *Public Advertiser*, January 30, 1770. (This capital piece is obviously "the dialogue on slavery" which Vaughan asked Franklin to send over from Paris for his 1779 edition, but which he failed to get.) Another item also recently recovered which likewise exhibits Franklin's craft as a writer is the set of three fables dedicated to Lord Hillsborough.

Although Franklin did not altogether escape the vice of hasty writing which appears in even the more leisurely journalism of the eighteenth century, the surviving drafts show that he was still a vigilant reviser. His letters reveal that he set great store by certain pieces, especially his satires of September, 1773, and for literary reasons among others. On the whole he preferred the "RULES by which a GREAT EMPIRE may be reduced to a SMALL ONE"—"as a composition for the quantity and variety of the matter contained, and a kind of spirited ending of each paragraph"—to the more spectacular hoaxing of "An Edict of the King of Prussia." It is a fact, possibly quite irrelevant, that an early draft of the favorite essay was jotted down on an invoice from Brown & Whitefoorde, Wine Merchants, for

6 bottles Sherry seal'd yellow Rose
6 Dº. Port seal'd yellow Cock
4 Dº. Claret seal'd yellow Star
2 Dº. Mountain seal'd red Cypher.

In the next year Franklin even suggested that the sting of these essays had brought about his public disgrace in the Cockpit, and the loss of his crown office as joint-deputy postmaster general for North America. The claim appears in a letter of February 19, 1774 which can safely be attributed to Franklin, although he concealed his authorship. It was published in the colonial press as a first defense of Franklin against the virulence of Wedderburn's attack. Written in the third person, the apologia points out:

> When People give weak Reasons for Strong Resentment, one is apt to suspect they are not the true ones; so I fancy sometimes, that the Doctor's returning those Letters could not be the Foundation of all this Fury, and that possibly the Preface to the Boston Pamphlet, the Prussian Edict, and the Rules for diminishing a Great Empire, are suspected to be his, and yet not mentioned, lest the Attention of the Public should be more turned towards those pieces, which are thought to expose the late Measures too poignantly.

Franklin's work as propagandist-in-chief for the colonies in England was often, to be sure, of a routine sort. There were documents from America to insert in the London press: resolves of town meetings in Massachusetts, of merchants and mechanics in Philadelphia, letters from colonial correspondents to be abstracted. Usually Franklin wrote an adroit paragraph or so of introduction; he also wrote prefaces for several of those American tracts which he got reprinted in London. In the launching of still other pamphlets his part appears to have been that only of paymaster to the printer. Several such transactions are revealed by Strahan's ledgers and by Franklin's accounts, as agent, with Massachusetts Bay.

There is singularly little evidence of Franklin's collaboration with other political writers: in general he played a lone hand. Richard Jackson's supposed partnership in the writing of the Canada pamphlet of 1760 is now discredited, his share reduced to supplying of some materials for Franklin's use. Another aide was John Huske, member of Parliament for Malden, Essex, an American by birth who probably wrote an important anti-French pamphlet of 1755, *The Present State of North America*. Huske made himself useful to Franklin on at least two occasions. On Franklin's examination in 1766, by previous arrangement no doubt, he asked a

number of the "friendly" questions which enabled the agent to shine so brilliantly before the House of Commons. And in 1768 Huske was the "merchant friend" who furnished the tables of British trade with the northern colonies and the West Indies which Franklin as "F.B." displayed and discussed for the readers of the *London Chronicle*.

Even Franklin's astonishing fertility was strained at times by the pressure to keep the American case before ministers and members of Parliament, or at all events before the newspaper-reading politicos of the clubs and coffee-houses. In an emergency he did not hesitate to repeat himself. At the height of the campaign for the repeal of the Stamp Act he secured the publication in the *London Chronicle* of his letters to Governor Shirley, written as long ago as 1754, in which he had anticipated so many of the later American arguments against parliamentary taxation. In 1774, a year when Franklin's fortunes and those of America took a sad turn for the worse, the "RULES" of 1773 were reprinted in the *Gazetteer* from an "authenticated copy" furnished by "A Fidler," who was certainly Franklin. To be sure, he adopted a rather thin disguise:

> Having lately had occasion to turn over some newspapers, published in the course of the last summer, in search of an advertisement, I accidentally stumbled upon a letter, containing many *excellent rules*, by which a *great empire* may be reduced to a *small one*.
>
> As I apprehend this plan is at present under the consideration of the House of Commons, I think a re-publication of it, at this time, would not be improper. The rules appear to me to be admirably adapted to the end proposed; and tho' the experience which we have since gained may enable a *shrewd politician* to improve upon some of them, there are others perhaps which will serve to furnish *Lord North* with some ideas that possibly may not hitherto have occurred to him.

In 1774, also, the *Chronicle* reprinted Franklin's essay of 1768, usually called "The Causes of the American Discontents." But it was now printed without those deletions which had caused the author to complain in 1768 that the *Chronicle* editor had shown himself a Grenvillite. It is pretty clear, then, that it was Franklin who in 1774 furnished a true copy to the *Chronicle*. In December, 1774, Rivington brought out the restored essay as a pamphlet from his press in New York.

It was in the critical year of 1774 that there was also printed, apparently for the first time, the well-known "Answer" which Franklin had written back in 1769, to certain "Queries" on American affairs which Strahan had raised in a letter to his American friend. Meanwhile, however, this document had been widely circulated in manuscript copies, as had been the case earlier with Franklin's "Examination." One copy of the "Queries and Answer" Franklin had sent to his Boston correspondent, the Reverend Samuel Cooper, and it eventually found its way with other Franklin letters into the possession of George III. Strahan himself had sent other copies to David Hall and William Franklin. Still another, he said, had been put in the hands of the Duke of Grafton and "the other Chiefs of the Ministry." Perhaps because of Franklin's pessimistic conclusion, that "Mutual Recriminations will . . . go on to complete the separation" between colonies and mother country, Strahan had warned Hall that it would be "highly improper to publish it, or risk its getting into the papers." But in 1774, as now appears, Franklin procured its printing in the *Public Advertiser*, and a little later in the *Gazetteer*.

Franklin's frugality had occasionally an amusing aspect. Several times, when writing anonymously or pseudonymously, he quoted himself with words of praise which no doubt concealed a private chuckle. Thus in 1770 as "The Colonist's Advocate" he cited a famous passage from his own examination with this admiring comment:

> For, what their Disposition, with Respect to the Mother-Country, was, before the Year 1763, is well known to the Publick, and justly described, in the following Words, by a Gentleman, who has done great Honour, and important Service to his Country by his Manly Defense of her Liberties.

Franklin practised another less obvious type of literary economy which throws light on his writing methods, and incidentally facilitates the search for the lost Frankliniana: the economy of ideas, of turns of exposition and argument, even of phraseology. Sometimes these echoes suggest that he was using certain well-thumbed notes and memoranda—notably one set of jottings which he seems to have prepared in advance of his examination in 1766. At other times it

would appear that his tenacious memory was drawing up old treasure from a well-stored mind. In the margin of the notes just mentioned was a stray jotting which read: "Germany the Mother Country of this Nation." Seven years later, in an essay which appeared in the *Public Advertiser*, March 16, 1773, Franklin expanded this note to refute the annoying assumption by many Englishmen that America was somehow their property. "Britain," he wrote, "was formerly the America of the Germans."

> They came hither in their Ships; found the *Cream* of the Land possessed by a Parcel of Welsh Caribbs, whom they judged unworthy of it, and therefore drove them into the Mountains, and sat down in their Places. These Anglo-Saxons, our Ancestors, came *at their own Expence*, and therefore supposed that when they had secured the new Country, they held it of themselves, and of no other People under Heaven. Accordingly we do not find that their Mother Country, Germany, ever pretended to tax them; nor is it likely, if she had, that they would have paid it.

Here he dropped the theme for the time being. But he returned to it in the fall, to expand it further into the elaborate hoax of the "Edict of the King of Prussia." This famous essay Woodfall printed on the front page of the *Public Advertiser* (September 22, 1773) though he placed it under a Danzig date-line, with the editorial explanation: "The Subject of the following Article of FOREIGN INTELLIGENCE being exceedingly EXTRAORDINARY, is the Reason of its being separated from the usual Articles of *Foreign News*." In a note to Franklin he explained more candidly: had it "been printed as a Foreign Article I feared it would have been lost, or at least not so much attended to as it deserved."

Among the many types of argumentation which Franklin used, one which most directly reflects his shopkeeping background was his practise of "stating an account." For instance, in the *Public Advertiser*, January 17, 1769, he itemized such an account for "The Right Hon. G.G. Esq; and Co. . . . with the Stockholders of Great Britain." Or rather he stated two accounts: one of the great losses already incurred from the American troubles, another of the immensely greater losses to be expected "if the Rupture hitherto only apprehended shall take Place," and war ensue. He concluded:

"Thus stand the Accounts; yet this same G.G. the Root of all the Evil, sets up for an Œconomist."

Franklin set up for something of an economist himself; and many of his arguments in the English press were directed at British folly in driving good customers away from the shop. These arguments were addressed more especially to the British merchants and manufacturers. Indeed, from 1767–1774 Franklin shaped most of his propaganda to reinforce in that quarter the successive colonial movements of economic pressure through withdrawal of trade. There is evidence that Franklin himself had a good bit to do with encouraging these non-importation, non-consumption, and home-manufacturing movements in America, from the early days when Poor Richard in his almanac for 1765 turned his preaching of industry and frugality into a political channel, to the later days when it was widely believed that Franklin's advice had helped to shape the Association of the First Continental Congress. However that may be, in England he was the press agent for non-importation, picturing again and again the losses of English trade already incurred, and the future losses to be expected; and in 1770, when the great non-importation league was breaking up, skillfully covering the American retreat. To this kind of propaganda belongs what appears to be Franklin's last important essay in the English press. In the *Public Ledger* for November 19, 1774, before news had come to England of the final action of the Congress, there appeared a sensational letter signed "An American" and addressed "To the Merchants of England." It contained a startlingly accurate prediction of the forthcoming restrictive measures of the Congress, with dire prophecies of their effects on the economy of England, Ireland, and the West Indies. Thomas Hutchinson read it, and in a letter to Thomas Gage fixed on Josiah Quincy, Jr., who had reached London just two days before on a mysterious mission for the Boston radicals, as the author. But this striking manifesto is not all in the younger Quincy's manner, and very much in Franklin's. In his two-hour talk with Quincy on November 17 Franklin had had ample opportunity to learn what was afoot in the Philadelphia Congress. It would therefore appear that this important forgotten letter was Franklin's last despairing attempt

to turn the tide of British policy in America by underscoring the threat of economic pressure: his last attempt through propaganda to save from shipwreck the old British Empire.

Franklin's espousal of the tactics of economic pressure had meanwhile worked some modifications in his own conviction that the American people should remain so long as possible a farmer society. Economic retaliation—even at the price of a certain measure of industrialism—he preferred to violent measure of popular revolt, chiefly because he long believed that America needed no sudden revolution; that time and a rapidly multiplying population were shifting the balance of imperial power to the western hemisphere. His repeated denials in the English press that Americans were seeking independence, as their opponents charged, were sincerely made. Until very late in the quarrel Franklin himself remained an Anglo-American imperialist. But his imperialism was of a special sort, not to be understood by crown lawyers or even by English Whigs of the eighteenth century, though quite in the present-day temper of the British Commonwealth of Nations.

For fairly obvious reasons the search for Franklin's underlying constitutional views—his notions of the true character of the British Empire and of the basis and extent of American rights within the empire—should begin, not with his published political writings in England, nor even with his correspondence, but with the marginal comments which he wrote in his own copies of the controversial pamphlets of the period. These secret jottings reveal that as early as the winter of 1765–6 his private views ran to a claim of what would now be called dominion status, within an empire united by allegiance to a single crown but not by subordination to a single parliament. From 1768 on hints of these principles, even then in advance of most American opinion, began to appear in his letters and in such newspaper essays as the "American" and "Briton" papers of September–October, 1768.

On the whole, however, until very late in the controversy, Franklin conceived his rôle as that of the expounder in England of prevailing opinion in America—and even, to some degree, as the interpreter of British opinion to the colonies. Again and again the discourse in his essays follows such a pattern as

this: "But perhaps it may be some satisfaction to your Readers to known what ideas the Americans have on the subject. They say . . . [etc.]" And of the American views thus introduced: "I relate them merely in pursuance of the task I have impos'd on myself, to be an impartial historian of American facts and opinions." At the same time he urged on the English government the importance of reckoning with American opinion, however perverse or heretical it might seem in the longitude of Westminster: "It has been thought wisdom in Government exercising sovereignty over different kinds of people, to have some regard to prevailing and established opinions among the people to be governed, wherever such opinions might in their effects obstruct or promote publick measures."

Indeed, the major impression which remains after reading the whole body of the Franklin political essays, is not so much of the cleverness of his propaganda devices, or of the sting of his satires, clever and even devastating as these essays often were, but of the statesmanlike sense of responsibility which on the whole they exhibited. If he deliberately suppressed the discussion of fundamental constitutional issues, it was not because he was intellectually lazy. Nor was it merely because as a prudent politician he realized that these issues were alarming to the "friends of America" in England, and might even disturb his comfortable status as an absentee crown official for America. The very fact that in his own theory of the empire he had early reached radical views made him the more hesitant to swing the debate in the direction of constitutional theory. For he understood that the hardening logic of the American case was irreconcilable with principles just as firmly held in England. And so as Francis Lynn he deplored, in 1768, "the public discussion of Questions that had better never have been started." But for "those unnatural and churlish-hearted Men . . . who, needlessly, wickedly, and madly sowed the first seeds of Discontent between Britain and her Colonies," he wrote in 1770, "Peace and Harmony would have reigned between the different Parts of this mighty Empire from Age to Age, to the unspeakable and inestimable Advantage of both." In the passage that follows immediately after this nostalgic invocation of empire, he makes

sufficiently clear the kind of empire that could hold his affections and those of his fellow Americans:

> Those men make a mighty Noise about the importance of keeping up our Authority over the Colonies. They govern and regulate too much. Like some unthinking Parents, who are every Moment exerting their Authority, in obliging their Children to make Bows, and interrupting the Course of their innocent Amusements, attending constantly to their own Prerogative, but forgetting the Tenderness due to their Offspring. The true Art of governing the Colonies lies in a Nut-Shell. It is only letting them alone. So long as they find their Account in our Protection, they will desire, and deserve it. This our Experience confirms. So long as they find their Advantage, upon the Whole, in carrying on a Commerce with us, preferably to other Countries, they will continue it. Nay, unless we compel them to the contrary by our unnatural Treatment of them, they will shew a Prejudice in our Favor. Whenever they find Circumstances changed to the contrary, taxing and dragooning will only widen the Breach, and frustrate what ought to be the Intention of both Countries, viz. mutual Strength, and mutual Advantage.

SYNTHETIC RUBBER.*

BY

E. R. BRIDGWATER,

Manager, Rubber Chemicals Division, E. I. du Pont de Nemours & Company, Wilmington, Delaware.

Mr. Chairman, Members of The Franklin Institute, and Guests: Rubber has frequently been said to be one of the most versatile of Nature's raw materials that man has pressed into his service, having in mind the wide range of properties that can be conferred upon it by compounding other materials with it and varying the conditions of vulcanization. There is no other structural material that combines the very high extensibility and almost complete elastic recovery which are the outstanding properties of soft vulcanized rubber and its synthetic counterparts. But I fear that from the scientific point of view, rubber and synthetic rubbers are unique in another and most unfortunate respect, namely, the very high ratio of the number of words that are written and spoken about them to the amount of exact information we have concerning them—if one may speak of the ratio between quantities that cannot be expressed in the same or any definite unit. So while I am deeply appreciative of the honor which has been conferred upon me by asking me to talk to you this evening, I approach the subject with a great deal of hesitation because I fear I shall have to devote more time to telling you what we do not know than to stating facts upon which an intelligent course of action could be based.

NATURAL RUBBER.

When a shallow cut is made in the bark of certain species of tropical trees, an emulsion called latex exudes. Approximately 62 per cent of the weight of the latex is water, the exact percentage varying with the seasons, climate, and age of the trees. In 1826, that versatile scientist Michael Faraday

* Delivered at the Annual Meeting of The Franklin Institute, Philadelphia, Penna., January 21, 1942.

demonstrated that approximately 90 per cent of the solids consists of a hydrocarbon having the empirical formula C_5H_8; and in 1860, Greville Williams destructively distilled rubber and produced in low yield a hydrocarbon which he called isoprene. In 1879, a Frenchman, Gustave Bouchardat, produced a substance remotely resembling natural rubber by polymerizing isoprene and postulated that natural rubber might be a polymer of isoprene. Chart I shows the structural formula for isoprene and the assumed structure of rubber hydrocarbon. Substantial support for this assumption has been provided by the work of later investigators who have identified chemical derivatives of rubber that would point to

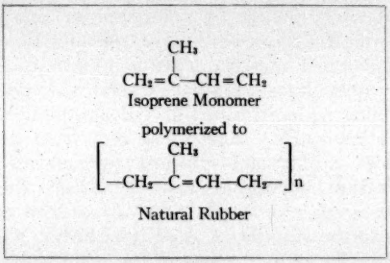

CHART I.

this structure. However, there is still a great deal of difference of opinion as to the value of "*n*" in the rubber formula, and about all that the various investigators are able to agree upon is that "*n*" is a large number and varies over a wide range depending upon the history of the sample under investigation. Obviously we cannot know how Nature synthesizes rubber nor can we even be certain that her synthesis passes through the stage of monomeric isoprene. We do know a great deal about the non-hydrocarbon solids in rubber latex, which consist chiefly of sugars, proteins, and resins. We know that some of these constituents serve as protective colloids to make the emulsion a reasonably stable one and that some of the nitrogen compounds serve as antioxidants.

DERIVATION OF SYNTHETIC RUBBERS.

Although it has been more than sixty years since isoprene was first polymerized to produce a remotely rubber-like material, no one has yet been able to discover conditions for polymerizing isoprene which will yield a product that even closely approaches natural rubber in strength and elasticity. If Nature does make rubber by polymerizing isoprene, she does it in an environment that man has not been able to duplicate. Hence there is no product that can be called synthetic rubber in the strict sense of the term.

Although rubber has never been synthesized, science has found means of producing polymeric substances differing from rubber in chemical composition but approaching it in physical properties much more closely than does polymerized isoprene. These rubber-like synthetic polymers have come to be called synthetic rubbers and I will use the term in that loose sense which has now become generally accepted. Five such products are in commercial production. They are:

(1) *Polymerized Butadiene.* The structural formula of butadiene and the assumed structure of its polymers are shown in Chart II. The commercial method of polymerizing

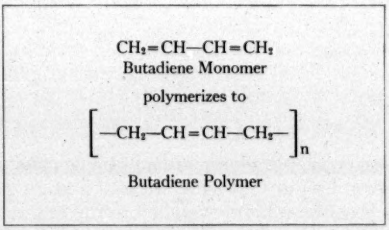

CHART II.

is to hold butadiene at a slightly elevated temperature for a period of days in the presence of metallic sodium which functions as a catalyst. To the best of our knowledge all of the Russian synthetic rubber is of this sort. Minor quantities of a similar product were produced in Germany before the war, but it was reported from Germany in the summer of 1939 that they had decided to drop production of this type in favor of

the interpolymers of butadiene with styrene and with vinyl cyanide.

(2) *Buna S.* This product, made by the interpolymerization of butadiene and styrene (Chart III), was developed by the I. G. Farbenindustrie A.G. and has been produced by them in Germany since 1935. We believe that this product accounts for more than 90 per cent of the German synthetic rubber production. Polymerization is effected by emulsifying butadiene and styrene in water with soap or a synthetic emulsifying agent and holding the emulsion at a slightly elevated temperature for a few days. There is no substantial production of the butadiene-styrene interpolymer in the

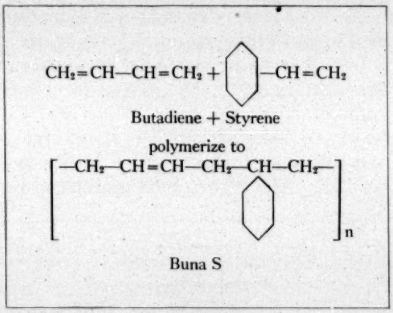

CHART III.

United States today, but plants are now being constructed with capital supplied by our Government, and a large expansion of these plants is contemplated even before the original construction has been completed.

(3) *Buna N or Perbunan.* This product, made by the interpolymerization of butadiene and vinyl cyanide (Chart IV), was also developed by the German I.G. and was first announced in 1935. Since the war broke out in Europe production has been undertaken in this country also where it is commercially sold under a variety of names, including the German name Perbunan. The various brands are not identical, differing slightly in the ratio in which the two com-

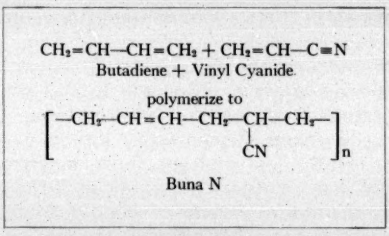

CHART IV.

ponents are present and presumably also in the nature of the emulsifying agents, polymerization catalysts, etc.

(4) *Polysulfide Rubbers.* These products have been made commercially in the United States since 1930 by the Thiokol Corporation and more recently similar products have been made in Germany. They differ from the other synthetic rubbers in that they are made not by polymerization but by the condensation broadly of an organic dihalide with sodium polysulfide. The condensation is carried out in an aqueous medium with the chlorine of the dihalide and the sodium atom of the polysulfide combining to form salt, which is removed by washing.

(5) *Neoprene.* This synthetic rubber, made by the polymerization of 2-chlorbutadiene (Chart V), was invented in the laboratories of E. I. du Pont de Nemours & Company in the late 1920's and the first plant for its commercial production

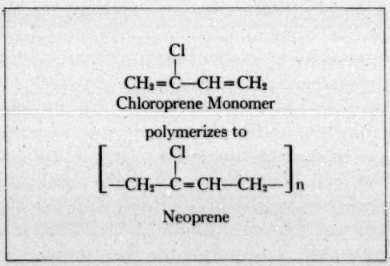

CHART V.

was completed in 1931. Chlorbutadiene, more commonly known as chloroprene, is made by the addition of hydrogen chloride to monovinylacetylene under the influence of a cuprous chloride catalyst. Monovinylacetylene is made by the condensation of two molecules of acetylene. Chloroprene is polymerized by emulsifying in water with soap or a synthetic emulsifying agent. The resultant emulsion polymerizes much more rapidly than emulsions of butadiene or the mixed emulsions of butadiene with styrene or vinyl cyanide. The time of polymerization, as with all such systems, is dependent upon the nature of the emulsifying agent and other components of the system and is normally only a few hours.

It should be pointed out that such names as neoprene, Buna S, and Buna N are in reality generic terms since there are many modifications of each of these products. Their properties may and do vary over a wide range depending upon the environment in which they are polymerized and, in the case of the Bunas, upon the ratio between the quantities of the two constituents. Polymerization catalysts are commonly employed which are usually oxidizing agents. When polymerization has been carried to the desired point, the emulsion is coagulated by some convenient means such as the addition of an acid or an electrolyte. Stabilizers may also be added to prevent further polymerization. A common type of stabilizer is the secondary aromatic amines.

Although only these five synthetic rubbers are actually being produced on a large scale, hundreds of other good synthetic rubbers have been produced in the laboratories of the various corporations who are working on this problem. For example, butadiene has been interpolymerized with other vinyl-substituted hydrocarbons than styrene. Methyl styrene and divinyl benzene are examples. Likewise, butadiene has been interpolymerized with chlorinated hydrocarbons, such as vinylidene chloride, and with a variety of alcohols and ethers, such as vinyl ethinyl carbinols and vinyl ethyl ether. Interesting synthetic rubbers have also been made by interpolymerizing butadiene with unsaturated ketones, for example, methyl vinyl ketone, and there are dozens of interesting products among the interpolymers of butadiene with unsaturated acids, esters, and nitriles, such as acrylic acid, methyl

methacrylate, acrylic and methacrylic nitriles, alpha cyano butadiene, etc. Some of these products have shown enough promise to justify the production of a few tons of material for extended practical trials but, to the best of the author's knowledge, none of them have so far displayed a combination of physical properties, together with low cost, which would justify their commercial production in competition with the synthetics now being produced. On the other hand, there is every reason to believe that further research will teach us how to make better butadiene interpolymers and better polymers of chloroprene. The fact that so many have been tried and been found wanting does not at all mean that we have reached the end of the road.

PROPERTIES OF SYNTHETIC RUBBERS.

Comparison of the properties of the synthetic rubbers now being produced is made difficult by the fact that the properties of all of them are influenced to a great extent by the manner in which they are compounded and the conditions under which they are vulcanized. Moreover, as noted above, the terms Buna S, Buna N, and neoprene are generic expressions representing a class of polymers which differ greatly among themselves depending upon the proportions of the polymerizable intermediates that are used in their production and upon the polymerization environment. With these limitations in mind I shall try to describe broadly the properties of each of the five types of synthetic rubber now being commercially produced.

The sodium polymerized butadiene polymer as made in Russia and formerly in Germany is inferior to natural rubber in practically all respects and is inferior also to the Buna S, Buna N and neoprene types. It may safely be said that its large-scale production is possible only when it is shielded from competition with natural rubber and the other synthetics.

The Buna S type displays properties quite similar to those of natural rubber when compounded with carbon black. This ingredient is universally used in all tire tread compounds and other rubber compositions required to have high resistance to abrasion. Hence tread type compounds made from Buna S compare favorably with tread compounds made from natural

rubber. However, when compounded without carbon black, Buna S is inferior to natural rubber in tensile strength and in elasticity. It would not make good rubber bands or elastic garments. Although greatly superior to the sodium polymer of butadiene, the Buna S type of synthetic rubber does not appear to have properties that would enable it to compete with natural rubber in a free market at the premium price which its higher manufacturing cost necessitates. This fact, however, does not detract from its suitability as a war-time substitute nor preclude its commercial production during times of peace if protected by an import tariff or aided by a subsidy, as has been the case in Germany.

The Buna N or Perbunan type is markedly superior to natural rubber in certain respects, especially in its resistance to deterioration by oils and solvents. By reason of its superior properties the I.G. Farbenindustrie was able before the war to produce it not only for use in their own closed economy, but also to find a substantial export market at a price several times higher than that of natural rubber. This type of synthetic rubber appears to have an attractive commercial future in specialty products where its unusual properties justify its higher cost.

The neoprenes have mechanical properties quite comparable to those of natural rubber whether vulcanized in a pure gum type of formulation or compounded with carbon black as for tire treads. They are superior to natural rubber in resistance to deterioration by sunlight, heat, and oils and also, due to their chlorine content, are relatively non-flammable. By reason of these properties they have enjoyed a sizable commercial market in the United States and abroad since 1932 in spite of the fact that they have been several times more expensive than natural rubber.

The polysulfide rubbers are superior to all the other synthetics in resistance to swelling by oils, especially by aromatic hydrocarbons. They are also quite resistant to oxidation deterioration, which property they share with the neoprenes and the Perbunan types. However, they are quite inferior to natural rubber in tensile strength and in elastic recovery, especially at elevated temperatures. Despite these

shortcomings, their excellent oil resistance has enabled them to find a substantial commercial market.

The physical properties of all synthetic rubbers and of natural rubber are greatly affected by the temperature of test. Hence, no conclusion can be reached as to the relative tensile strength, tear resistance, elastic recovery, or abrasion resistance of two or more samples without specifying the temperature of test or use. Elasticity is also a function of direction and magnitude of the distorting force, and the time cycle of distortion and recovery. A sample of neoprene, for example, may under certain test conditions be more elastic than a rubber sample of similar type and be less elastic under other conditions of test or use. The danger of allowing oneself to reach conclusions of broader scope than the range of experiments justify is ever present in scientific and engineering investigations. This pitfall is nowhere more dangerous than in the study of the properties of rubber-like materials.

SYNTHETIC RUBBER'S USES DURING THE EMERGENCY.

It would be foolhardy to assert that synthetic rubber can be made to serve as well as the natural product in all of the thousands of places in which our industrial and military machinery has employed natural rubber. However, we can take great comfort from the fact that during the past ten years our rubber manufacturers have adapted synthetic rubbers to thousands of uses for which they have been found to be superior to the natural product. In so doing they have acquired a background of experience that will stand them in good stead in this emergency.

During the past eight years many of our leading tire manufacturers have produced tires made wholly of neoprene and tested them under a wide variety of conditions of service with results that have been generally quite satisfactory. In addition, tires of all types and sizes have been made with a neoprene tread and a rubber carcass. These tires also have given a satisfactory account of themselves, and under some conditions of service have proved to be outstandingly superior to tires made entirely of natural rubber. During the past eighteen months one tire manufacturer has sold to the general public thousands of tires built with a tread compound

reported to be made from the Buna S type of synthetic rubber and again the service experience has been quite satisfactory. All of this does not mean that our rubber manufacturers face an easy task. The adaptation of synthetic rubbers to purposes for which natural rubber has been used requires not only reformulation of the compounds, and modifications of processing methods, but also a careful analysis of the engineering problems involved. For example, vibration absorbing mountings for engines of trucks and other military automotive equipment and industrial machinery will present many difficult engineering problems. There is no doubt that synthetic rubber can be used, and perhaps with even better results than have been obtained in the past from the natural product, but the mechanical characteristics of the new mountings will be different and changes in dimensions and method of installation may be required in order to obtain the best results. This is only one example of the many difficult problems that a complete cessation of supplies of crude rubber would create. It is as though all sources of steel were cut off but aluminum were made available in equivalent volume. Aluminum is an excellent structural material—better than steel in many respects—but the substitutions could not be made overnight.

SYNTHETIC RUBBER DEMOBILIZED.

No one can forecast what will happen to our new synthetic rubber industry when peace returns since no one can foresee the economic conditions in the post-war period. Since the industry is in the early stages of its development, it can safely be expected that the war-time plants will suffer rapid obsolescence; but if the plants we build now become obsolete, it will be because we have learned how to make better products at a lower cost. At least we shall be in a position to benefit from the great increase in our knowledge with respect to the manufacture of synthetic rubber and its practical application in our industries.

PHOTOPHORESIS AND ITS INTERPRETATION BY ELECTRIC AND MAGNETIC IONS. *

BY

FELIX EHRENHAFT.

I. EXPERIMENTAL FACTS ABOUT PHOTOPHORESIS, ELECTRO- AND MAGNETOPHOTOPHORESIS.

The experiments were carried out in an Ehrenhaft condenser (1) with a plate diameter of 8 mm. A vertical electric and magnetic homogeneous field absolutely free from residual electricity or magnetism was applied when needed. The strength and direction of this field could be chosen. The last description of the apparatus and the method is also given in "Photophorese, Electrophotophorese, Magnetophotophorese," *Annales de Physique*, 13, 151, 1940.†

The arrangement allowed the directing of a beam of light from the right, from the left or from both sides simultaneously through the space between the condenser plates. Each of these beams could be screened off instantly and could be weakened at will. Since each of the illuminating lenses could be shifted in the three dimensions of space, the intensified beams could be placed at any positions relative to each other, or diffused light could be applied from one side and a coaxial beam could be concentrated and applied from the other side. The visual field of the microscope was arranged at right angles (horizontally) to the light beam.

Particles of different substances were led to the space between the condenser plates. If only diffused light was applied for illumination one could see the particles fall with constant velocity only superposed by Brownian movement. The velocities depend on their sizes (mobilities). A guard ring condenser was provided which allowed the rising and the holding of charged particles for a practically unlimited time

* A short summary of this paper has been given in Science wkly vol. 94 (1941), 232.

† The apparatus in which the phenomena were observed was rebuilt by Carl Zeiss, Inc., New York.

and their movement to any desired place in the condenser. Thus the possibility was given to repeat one experiment on a single particle many times and to determine the mean values of velocities. All experiments were carried out in carefully cleaned inert gases.

1. Longitudinal Photophoresis.

A beam of concentrated light is applied from one side. Particles of the same kind and size then move under the influence of the light. Some move away from the light (light positive) [(1) p. 835] some toward the light (light negative longitudinal photophoresis) [(2) p. 952] (Ref. 1 to 11) [(56) see fig. 5, p. 386]. This was also observed by R. Whytlaw-Gray and Patterson (Leeds) (42), who performed these experiments quite independently of the authors, and also by many of his own pupils (15, 27, 28, 29, 37, 38, 39, 40, 41, 43, 44). The movement depends upon the material and the intensity and the frequency of the light beam. The phenomena were also observed in liquids by the author's pupil Satiendra Nath Ray (34) (Lucknow, India) and independently of the author by W. W. Barkas (35) (London). The latter also found photophoresis with X-rays.

Since the velocity v of a particle in the beam is found uniform it can be considered a measure of the force P acting on the said particle thus giving the relationship $v = P \times B$, where B is the mobility of the particle.

The weights of the particles were of an order of magnitude down to 10^{-10} dynes. All photophoretic forces were compared with this weight. Therefore the measurement of forces are more sensitive by the factor of 10^4 than any direct measurement of forces made thus far.

It should be mentioned that all particles do not show photophoresis. A certain number of particles stand still at first and only start to move after some time elapses. Others do not move at all. Changes in the velocity of the movement occur sometimes during short periods and at other times after hours (11) (41). Some particles even change their direction of movement spontaneously. The mechanical properties of these particles however were not changed.

If the direction of the beam is reversed the direction of movement of the particles is in almost all cases also reversed. By means of an electric field in the direction of the light beam the movement of a particle can be accelerated or retarded at will (37). It is also possible to make a particle stop and thus to compensate the photophoretic force. Furthermore it is also possible to compensate the movement by means of two symmetrical beams.

2. Electro-Photophoresis.

If two symmetrical light beams are applied from two sides the longitudinal photophoresis disappears. If in that arrangement an electric field perpendicular to the light beam is applied a movement in the direction of this field takes place, which phenomenon the author calls electro-photophoresis (8, 37, 38, 40, 43). The speed of this movement depends on the intensity of the light, on its frequency and on the intensity of the field, and is different for the various materials. Some particles do not show such a movement, some start suddenly and others change their direction of motion spontaneously or move with a decreasing speed (41). The electro-photophoretic velocity is proportional to the intensity of the light and to the strength of the electric field but for high fields saturation values are observed (41). It is remarkable that the dependency of the velocity upon the material is sometimes very great i.e., Te, Sb and As require about 1000 times smaller field-strength than Se. In other materials such as oil and sulphur as well as phosphorus no electrophotophoresis has been observed.

3. Magneto-Photophoresis.

When a homogeneous magnetic field is applied at right angles to an intense beam of light as described above some of the small particles start moving with uniform velocity, the value of which depends upon the particles mobility. Some of the particles move toward the North some toward the South magnetic pole [Ehrenhaft (8, 39, 56)]. The rising particles are lifted against gravity and the falling particles fall faster. Others do not show any change in their motion. The motion due to the photophoretic force ceases instantly if the light is

shut off. The speed of the magneto-photophoresis depends upon the intensity and the frequency of the light, and upon the intensity of the magnetic field as well as on the material itself. For nickel and iron particles, for instance, the intensity of the geomagnetic field is sufficient to produce a movement in both directions, if, as in the case of the author's laboratory in Vienna (Austria), the direction of the geomagnetic field is vertical and its intensity about 0.4 Gauss (the horizontal component was negligible because of the iron in the building). This movement could be annulled by an inverse magnetic field of the same strength. The movements of the particles are reversed if the magnetic field at sufficiently high strength is reversed. The photophoretic force is a linear function of the field if said field is weak (56). At higher fields saturation values were observed and the magneto-photophoretic velocity was independent of the magnetic field strength. There is therefore no dependency upon the history of the particle. A discussion of ferromagnetic particles in high fields is given in Ann. de Phys., p. 166 (53). Ferromagnetic particles reverse the direction of their movement with the reversal of the field with very few exceptions. Diamagnetic particles reverse the direction of their movement in high magnetic fields (39, p. 655, Statistic). In lower fields they do not follow the fields in all cases (sometimes the rate is 50 : 50) and in still smaller fields the spontaneous reversal of the direction of movement occurs so fast that it cannot be counted.

4. The Trembling-Effect.

This rapidly changing movement of diamagnetic particles in low fields cannot be confused with Brownian movement in gases, discovered by the author (1905) (60) because it is of another magnitude and kind. After the discovery of the Trembling effect by the author it was also observed by I. Parankiewicz, J. Mattauch (20), E. Reeger (39), B. Whytlaw-Grey and H. S. Patterson (42) (p. 122). The latter two independently working in Leeds (England). Those particles did not show any change of physical properties, if examined after they executed the Trembling-motion for a long period. It should be noted that this motion is also possible in the geomagnetic field.

5. Other Remarkable Facts.

Rising particles remain on the upper edge of the light beam and stay there. After a short while the whole upper edge of such a beam is filled with such particles. This was observed by the author, E. Reeger (39) (p. 651), E. Wilflinger (40) and Whytlaw-Grey and Patterson (42).

The fluctuations in the velocities of the electro-photophoresis was found to be much smaller in ultrared light than in natural light (43).

II. THE INADEQUACY OF THE EXISTING THEORIES TO EXPLAIN THE PHENOMENA.

At first the author tried to explain the phenomena as far as they were then known by light pressure and radiometer theories (1910) [(1), p. 836]. Later he had to recognize that those forces did not explain the facts (1918) (5). Other suggestions as made by F. Michaud (Paris) (16), P. Epstein (Pasadena) (17) and T. Terada (Tokyo) (18) did not give satisfactory explanations, any more than those of A. Rubinowicz (Munich) (22, 23, 24), G. Laski and F. Zerner (25, 26), O. Halpern (32) and others. After the discovery of electro-photophoresis and magnetophotophoresis the author and his pupils tried to apply the radiometer theory to explain the phenomena (13). The discovery of the photophoresis in liquids by Satiendra Nat Ray (25*a*, 34), W. W. Barkas (35) and G. Fachini (36) complicated the situation considerably.

The following are the main difficulties which are encountered in an explanation by radiometer forces.

(*a*) There are silver spheres which exhibit a tremendous light negative motion though, as the most strongly reflecting of all substances silver certainly ought to be most heated on the side toward the light (2, 4, 41).

(*b*) It is known that selenium spheres of equal size in hydrogen, nitrogen and argon, experience the same photophoretic negative force though the conduction of heat and the gas viscosity are very different in the three gases [(15), *Ann. der Physik*, p. 513].

(*c*) As above mentioned the photophoresis was also found in liquids, where radiometer forces are impossible because of the short mean free path of the molecules. W. W. Barkas working in the University College laboratory in London

(directed by Porter and Andrade), has shown that single colloidal particles of the same kind (gold, silver, copper or oil) were both light positive and light negative, and that the forces are of the same order of magnitude as those which Ehrenhaft and others measured in gases (35).

(*d*) It does not seem possible to explain the reversibility of the particles by reversals of the (electric or magnetic) field on the basis of radiometer forces. Some particles could be reversed a hundred times and more. The field intensity E or H does not have a bearing on solely the orientation of the symmetrical or asymmetrical particles. The energy of H or E which is alone responsible for orientation is a quadratic function of the potentials. Therefore it cannot change when the potentials are reversed, i.e. E or H. However, the particles immediately do change their direction of motion.

(*e*) Let us consider a symmetric or asymmetric particle at the lower edge of the beam, so that its upper part being inside the beam will be hotter than its lower part. Thus radiometer forces could only repulse such a particle from entering the beam. But it has actually been observed a number of times by the author as well as by others (37, 38, 39, 40, 42) independently of him that under the influence of E or H particles moved upwards and across the beam.

(*f*) The motion of particles of iron and nickel across the beam occurs frequently without an artificial vertical magnetic field. The explanation is given in the interesting dissertation of N. Judenberg 1938 on the basis of work done under the author's direction at the University of Vienna. The exact diagram of the arrangement has been published *Ann. de Phys.*, 13, 161, 1940 (Paris). The direction of the geomagnetic field intensity of his laboratory room was vertical on account of iron in the building and was of a magnitude of 0.4 Gauss. *This geomagnetic field alone without any artificial field caused nickel particles to move upwards.* When this homogeneous field was compensated by an artificial field of the same size but of reverse direction the motion resulting from the geomagnetic field ceased instantly.

(g) The radiometer theory cannot explain the typical difference between the behavior of ferromagnetic and the diamagnetic substances in the condenser. Ferromagnetic

particles almost always reverse their motion when the magnetic field is reversed, but diamagnetic particles very often change their direction of motion spontaneously. The number of spontaneous reversals with the magnetic field depends upon the strength of this field. If the magnetic field is of great intensity the spontaneous reversals do not occur, but they happen more often as the intensity of the field decreases until such spontaneous reversals are so numerous that they cannot be counted. This occurs sometimes at fields of about 3000 Gauss (8, 39) sometimes even in the geomagnetic field. It is known that a particle in the Ehrenhaft condenser cannot be charged if it is in a large electric field. The sudden changing of movements (Trembling-effect) occurs only in low magnetic fields. It seems almost impossible to explain the Trembling-effect as a mechanical thermal effect, especially since this effect occurs only in fields of a certain strength.

(*h*) The photophoretic force is a linear function of the field if it is weak. This applies to the electro- as well as to the magneto-photophoresis.

(*i*) It is well known that asymmetrical bodies will orientate themselves in E or H (in the case of H regardless of whether they are ferro-, para- or diamagnetic) so that the longest diameter comes to lie in the direction of the lines of force for well known energy reasons. Experiments show that for these bodies the direction of the electrophotophoretic force as well as the direction of the magneto-photophoretic force are entirely independent of the direction from which the light is coming (defined by its wave front normal): for this motion always follows the direction of the respective field. Were we dealing with radiometer forces either of the Crookes type or by assuming a dependency of the accommodation coefficient upon the magnitude of the field, than the direction of motion would still have to depend upon the direction of the incident light upon which, in turn, depends the distribution of temperature on particles whether symmetrical or asymmetrical. (E. Reeger (39), G. Placzek (37), P. Selner (38).)

(*j*) It seems worth while to mention that some particles start to move suddenly from rest. It was also observed that for other particles the photophoresis sometimes suddenly disappeared and sometimes decreased or increased gradually.

[(15) Parankiewicz] [(27, 28) Mattauch] Isser & Lustig (43), G. Placzek (37).

(*k*) The particles showed no changes of velocity in ultra-red light ($\lambda > 750$ mμ), but the same particles frequently showed changes in white light. If the phenomena could be explained by heat effects it is not clear why the white light should cause the effects but not the much hotter ultra-red light (Isser & Lustig (43)).

(*l*) Silver particles, which were analyzed for mechanical qualities and found to be the same differ in their behavior in the photophoresis. Some of them are light positive, some are light negative and some keep changing from the light negative movement to the light positive one and (41) vice versa.

(*m*) It is also very difficult to explain the fact that photophoresis can also be observed with X-rays.

III. THE INTERPRETATION OF THE EXPERIMENTS.

1. The Difference between Electricity and Magnetism.

The prevailing opinion is that within an arbitrarily chosen geometric surface a real quantity of either kind of electricity can be inclosed ($\operatorname{div} E = \rho$), but no matter how the surface is chosen, it will always inclose the same amount of north and south magnetism ($\operatorname{div} H = 0$). In other words there are true quantities of electricity of either sign, but not true magnetic quantities. Thus we have electric but not magnetic currents. The author and Dr. Leo Banet showed (59, 83) that the above mentioned assumption was based upon two so-called fundamental experiments:

A. The broken magnet gives two entire magnets with equal poles.

B. A magnet put into a vessel floating upon water shows direction and no motion. Therefore there can be no excess of charge. (Conf. J. C. Maxwell, "Treat. on Electr. & Magn.," 377–379.)

Ad experiment *A*: This experiment does not prove to be right. To see this one only has to take a piece of demagnetized iron wire and break it into two without using any tools. Often such pieces are then North or South magnetic at the broken ends while the other ends remain almost non-magnetic. The effect is the same when a nonelectrically

glass or sulphur rod is broken and shows at the ends various kinds of electric charges. This phenomenon is easily explained since each breaking creates constriction. Each constriction however creates electricity and magnetism.

By means of such experiments it can not of course be proven that div H could not be zero on such pieces, but they undoubtedly indicate that experiment A is not conclusive. From experiment A cannot thus be concluded that div $H = 0$.

Ad experiment B: The historic facts are as follows: As early as 1269 Peter Peregrinus described the basic arrangement for experiment A as well as for experiment B (61). Later Robert Norman found that there is no motion of a floating magnet toward the rim of the vessel (62), as was also confirmed by W. Gilbert (63). Finally J. C. Maxwell concluded from the above mentioned experiments that div H is zero generally and under all circumstances. It can be easily seen that the mobility of the floating magnet (about 10°) is much too small to show small differences in the strength of magnetic poles. Just as small electric charges can be measured on small particles of great mobility (10^{6} or more) in gases moving in a homogeneous electric field (Ehrenhaft condenser) (1) so the movement of submicroscopic particles (with a mobility of about (10^{7}) in a homogeneous magnetic Ehrenhaft condenser (7, 7*a*) enables us to have the most sensitive arrangement of the Peregrini-Maxwell experiment of a floating magnet in a homogeneous field. From this it should be clear that only by means of experiments of such a sensitivity could it be determined whether single magnetic poles (charges) exist or not. The fundamental experiments mentioned above are not sufficient to demonstrate that magnetic charges cannot exist. This had to be presupposed before an interpretation of the experiments of the photophoretic phenomena could be given.

2. The Interpretations of the Photophoresis.

In order to explain the phenomena of photophoresis one conclusion is drawn from the movement of the illuminated particles in the homogeneous electric and magnetic fields. The *light induces electric and magnetic charges (poles) upon the particles if they are illuminated by concentrated light pre-*

ponderantly shorter wave lengths. In the case of the electric charges it does not seem to be so strange since light ionizes the matter as is well-known. It is furthermore known that the ultraviolet part of the light is more active and that it changes the charges of single particles (Elementary photo-electric effect direct and inverse (64, 65, 66, 67, 68, 69, 70)). For the magnetic *charges this conclusion is new, but is justified because of the complete analogy of this phenomenon with the electric phenomenon.* This conclusion is not only justified because it gives a satisfactory simple explanation of all photophoretic phenomena as will be shown later but because it is also able to explain a various number of hitherto unexplained phenomena and allows the drawing of new conclusions which can be verified. This demonstrates the heuristic value of a theory in all cases.

It should be noted here that there are no empirical facts which contradict this conclusion as was shown above. The difficulties such an explanation encounters are not due to experimental facts but only to *theoretical* considerations which go back as far as Ampere who introduced the hypothesis of molecular currents and reduce the phenomena of magnetism to purely electrical phenomena.

3. Discussion of the Phenomena.

We shall now attempt to give the discussion of the phenomena as described in (*a*) to (*m*) but in another order.

To (*d*): It is obvious that the particles if they are charged have to follow the direction of the electric as well as magnetic field if these are reversed.

To (*e*): For the same reason as above the particles cross the beam upwards.

To (*f*): It is clear that the particles which were moved by the geomagnetic field across the beam had a magnetic charge since their movement could be compensated by an artificial magnetic field of the same strength but of opposite direction.

To (*g*): A change of direction of movement in the electric or magnetic field must be due to changes of the charge of the particle. Such changes can occur spontaneously while a low field is applied or when the field is reversed since in that case for a certain time no field acts on the particle. As it is well-

known particles in high fields do not change their electric charge but they do so under low or neutral fields. The phenomena in the electro- and magneto-photophoresis occur in the same way. Therefore we can understand why changes of direction occur only in low and neutral fields, sometimes so frequently that they cannot be counted. This phenomenon has been called by the author the Trembling-effect. *The Trembling-effect is thus a very frequent change of magnetic poles in the intense beam of light and the magnetic field.* It can occur even in the geomagnetic field.

To (*h*): It should be noted that it is only a primary effect that is characterized precisely by a linear relationship between its elements. The origin of this concept is the law of Hooke: Ut tensio sic vis. The same concept was used later in the development of the electromagnetic theories, by J. C. Maxwell expressed in the equations $D = \epsilon E$, $B = \mu H$, which equations were true only in certain cases and for small values of E and H. We have found that the electro- and magnetophotophoretic forces are linear functions of the electric or magnetic field (E or H), if these are weak. This indicates that the photophoresis is a primary effect.

To (*i*): It seems clear that it does not depend on the direction from which an electric or magnetic charge is induced. The particle always follows the applied field. On the other hand it seems impossible to explain this phenomenon by any theory which deals with differences of temperature of the bodies.

To (*j*): These phenomena show an exact analogy to the phenomena of sudden and slowly charging of electric particles as observed during the determinations of electric charges.

To (*k*): It is striking that ultrared light which produces a much greater heating effect has not as much influence as light of shorter wave-lengths. The violet part of the light seems to induce these charges to a greater extent.

Since light makes particles of matter unipolar with respect to homogeneous electric and magnetic fields and since, when no such fields act, it makes them move in or against its wave front normal and since, as has been shown above, radiometer forces cannot account for this movement, we are driven to suppose, that the light brings into play upon the particles

forces which are perpendicular to its wave front normal. It is the belief of the writer that these forces are of the nature of electric and magnetic fields, which exist as part of the whole ensemble of light, surrounding medium and particles within the chamber of observation. It must, however, be stated here that, as will be shown later, the forces exist under all observed conditions, such as different gas pressures down to 4 mm mercury pressure, in liquids and in condensers and chambers of observation of different kinds and sizes. (83, Fig. 1). S. Patterson and R. Whytlaw Gray (30a) (42), for instance, observed light positive and light negative photophoresis with velocities up to 1 cm sec in the center of a vessel containing one liter, using a microscope of low aperture.

Such an idea touches upon the basic problems of light. May I recall here what Ernest Mach said (Erkenntnis und Irrtum, Leipzig, 1905, p. 241): "In the theory of optics one speaks about light waves while only the periodicity is required for the understanding of the facts. These accessorial elements which go beyond the necessity are the elements which are changed by the interconnection between thinking and experience." In order to perceive the periodicity, i.e. the oscillating components, of the light it is necessary to study its effects upon matter. If one talks about the oscillating components in empty space, it is a question of an extrapolation (i.e. carrying over conditions from the observable to the unobservable). One can observe in the experiments of photophoresis that particles of the same kind and size move simultaneously toward and against the propagation of the light and that they move in or against the direction of homogeneous electric and magnetic fields. Thus we need in the above case also matter to find the essence of the light beam. The movement of matter in or against the direction of the wave front normal has also been observed in liquids (34, 35, 36). It is known that spherical particles of equal size experience the same photophoretic force in (15) hydrogen, nitrogen and argon. Furthermore, all experimenters working in this field have found many particles whose photophoretic force, perpendicularly to the wave front normal, has been independent of the gas pressure to a very high extent (28, 4, 15). Such experiments were carried out down to pressures of 22 milli-

meter mercury (28). At these pressures the mean free path of the molecules is already large compared with the size of the particle itself. And even at pressures of 4 millim. mercury, where the vacuum can be considered as very good for testing bodies of a size of about 1.5×10^{-5} cm a distinct movement was observed toward the light by Mattauch and Ehrenhaft (28). If one says that the electromagnetic waves have longitudinal stationary components of E and H and potential differences along two points of a beam, this means only, according to Mach, an economical description of observable facts.

This result can be supported by the older theories of light. The electron theory (Paul Drude, Woldemar Voigt) applied to light demonstrates from the phenomena of absorption and dispersion that an electrostatic field exists in the direction of propagation of a stationary beam of light. (Festschrift Heinrich Weber 1912.)

From similar experiments of photophoresis it can be concluded that stationary magnetic fields exist in the beam of light since superposed magnetic fields accelerate or retard the longitudinal photophoresis.

It therefore seems to the author that the longitudinal photophoresis is an electromagnetic phenomenon. The movement of particles in a concentrated beam of light is completely analogous to the movement of the particles in an electric or magnetic field. Therefore the phenomena a, b, c, l, m can be explained as follows:

(a): Since the movement of a silver particle as well as that of any other kind depends upon its charge it can be understood why light positive and light negative silver particles are found.

(b): Since the force is an electromagnetic one it does not depend upon the conduction of heat or gas-viscosity.

(c): The movement of particles of the same kind in liquids can be understood as produced by poles and fields.

(l): Both slow and fast changes of direction of movement of silver particles are due to change of charge.

(m): Since the X-rays constitute electromagnetic waves of very short wave-lengths it can be understood that X-rays show similar phenomena as light.

IV. CONSEQUENCES.

1. The Charge of the Magnetic Ions.

Using the complete analogy of Coulomb's law of electric and magnetic forces it is now possible to determine the pole strength (charge) of a single magnetic ion. If P denotes the force acting on the particle due to the magneto-photophoretic effect, e_m the absolute magnetic pole strength for a certain intensity and wave-length of light and H the magnetic field intensity, then

$$P = e_m \times H.$$

The magnetophotophoretic velocity of the motion in a viscous medium is proportional to the magnetophotophoretic force. Thus we have $v_m = PB$ where B is the mobility. Furthermore for the velocity of fall in diffused light (due to gravity alone) we have $v_t = mg \times B$ where m is the mass of the particle and g the acceleration due to gravity. Then we derive for the magnetic pole strength (charge of the magnetic ion)

$$e_m = \frac{v_m}{v_t} \times \frac{mg}{H}.$$

The weight of spherical particles whose density is known can be determined by using Stokes law and its corrections. The author's method of precipitating the particles to be measured in the condenser and placing them under a microscope to determine their size can also be used (54, 56, 82). As examples a few figures for "the true magnetic charges" are given here, as obtained from successive points using different values of H and assuming the sphericity of the particles. (See JOUR. FRANK. INST., Sept., 1940, Fig. 8, −1, 2, 3.) Evidently in these curves constant slopes indicate constant charges, every change of slope indicates a change of charge. The result of this computation is given in the following table:

No.	Radius	Magnetic charge
28	0.79×10^{-5} cm.	-0.29×10^{-10} m.s.u.
32	0.86×10^{-5} cm.	-0.52×10^{-10} m.s.u.
33	1.02×10^{-5} cm.	$+3.21 \times 10^{-10}$ m.s.u.

The following values were used for the constants: the constant A of Stokes-Cunningham's law was 0.8, the mean free path of the gas molecules 1×10^{-5} cm., the coefficient of viscosity 1.76×10^{-4} g./cm. sec., and the density of Ni 8.5 g./cm.^{3}.

Let us compare these magnetic charges of single nickel particles with the electric charges of single small spheres as determined by the author, using his method formerly described. His most recent determinations, described in "The Microcoulomb Experiment" (Charges Smaller Than The Electronic Charge) (82) (p. 4) gave such values, f.i. 4.38, 8.50, 3.34, 2.9×10^{-10} e.s.u.

This shows the remarkable fact that the numerical value of the magnetic charge on a particle is about the same as that of the electric charge on particles of the same size. It should be mentioned here that the applicability of the Stokes-Cunningham law which requires that the particles have the same density as larger bodies and that their shape is spherical, had to be assumed in the calculation of the magnetic charge. In case of the electric charge it has been proved (82) that this assumption was justified. For this purpose the velocities of rise and fall had to be measured at various gas pressures up to 20 atmospheres, the test particle being caught and precipitated on a small quartz plate, and a new optical procedure had to be worked out to determine the actual shape, size and density of each individual particle.

2. The Magnetization of Matter by Light.

After the author concluded that there are stationary magnetic fields in a beam of light with accompanying potential differences and that light induces magnetic charges, he concluded that the light must have a magnetizing effect and stated in his paper (59) that the charge of a magnet could be changed by light. He asked his former pupil and now coworker Dr. Banet to study the literature on this subject (58, 59). Thereupon Banet found the following facts:

Even before the time of Oerstedt's experiments Domenico Morichini (1812) (71) magnetized compass needles by means of the ultraviolet portion of a sunlight spectrum as used by

Herschel. His experiments were verified by M. Sommerville (72), F. Zantedeschi (73), von Baumgartner (74) and others.

The author therefore together with Dr. Banet undertook to test the photomagnetic effect also on larger bodies (58). The experiments were successful with compass needles as indicators and a beam of light which was rich in ultraviolet radiation. Magnetic charges were induced on various unmagnetized annealed pieces of iron (paperclips, nails, little iron rods) which were placed normal to the geomagnetic field and which were irradiated for periods varying from minutes to several hours. The poles were mainly north magnetic (as mentioned already a century ago by von Baumgartner, Vienna) and were still present in many specimens after several days. Some were discharged almost instantly. After short periods of irradiation of iron wires it was found that the effect was only on the irradiated side and on the surface. After longer irradiation periods saturation values were obtained. Naturally, the magnetization was dependent to a high degree on the material, its surface and its history. This can be easily understood from the enormous differences in the various sorts of iron. Sometimes the magnetization could not be found at all for these or other reasons. We can now understand why Riess and Moser (75) (1829) and recently Charles M. Focken (Nature 148, 1941, 438) did not succeed to magnetize iron and therefore discredited the experiments of Morichini and others. In later experiments the author and Dr. Banet convinced themselves by means of an amplifier and oscillograph in the laboratory of the Amplifier Company of America that the characteristic of an induction coil with an iron core was changed by ultraviolet irradiation. We remind here that from a swarm of colloidal particles of iron and nickel only one part gets magnetized by light. This proved the author's belief that the magnetization is a general phenomenon as was observed in the magnetophotophoresis and that the magnetization of iron is only a special case. *Light thus magnetizes matter.*

3. The Influence of Light on Brownian Movement and on Diffusion.

Before the theory of Brownian movement was given by A. Einstein and Maryan von Smoluchowsky it had been ob-

served by almost all experimenters that an influence of light upon Brownian movements in liquids existed. As is well known the theory of Brownian movements considers only the statistical movement of molecules and does not account for any such influence. It should be noted that V. Pospisil when observing (1930) carbon particles in liquids in polarized light found that the motion is amplified in the direction of the magnetic vector. R. Fuerth and his school found that the movements of gold particles in liquids diminished in the direction of the electric vector. From other quarters, also independently from the author, the influence of photophoresis was rightly suggested as the cause. (Cf. *Phys. Zeitschr.*, **39**, 194 and 198, 1938.) The author after his discovery of Brownian movements in gases (59) has repeatedly stated that the statistical theory of Einstein and Smoluchowsky does not suffice to explain the phenomena (76, 77, 78). He showed, in a letter to the editor of the *Physical Review* (79) regarding Diffusion, Brownian movement, Loschmidt Avogadro's number and light in connection with magnetophotophoresis that to the statistical fluctuations the movement caused by photophoresis of any kind had to be added. Particles with induced magnetic poles have to move in the direction of the geomagnetic field. *Furthermore the diffusion itself must depend upon the light if observed in light.*

It is obvious that this knowledge is of great interest to the medical and biological science as well as to physiologists and others.

Since the fluctuations of Brownian movement were thus increased by photophoretic movement the determination of the Loschmidt-Avogadro number of molecules by this method gave too small values. *One should therefore make measurement of Brownian movement and diffusion without illumination or with checking light sparks.*

4. The Coagulation of Matter in Light.

The author observed in his condenser that particles coagulated faster when more light is applied. This has to be explained by the fact that the induced poles attract each other. It should be mentioned here that Fachini (36) who also observed photophoresis in liquids also found such coagulations. Furthermore, it is well known that light of short

wave-lengths increases particle size of colloids more rapidly than light of long wave-lengths (81).

It is obvious that these phenomena will also interest biologists and astronomers.

5. The Growth of Crystals Toward Light.

A pupil under the direction of the authors after observing photophoresis gathered the light negative and the light positive particles of tellurium separately and precipitated the single particles on quartz lamelle (for the method confer (54, 82). It appeared then that the light positive particles were amorphous spheres while the light negative ones were crystals. On the surrounding glass of the condenser precipitation took place on both sides of the surrounding glass, toward the light and away from the light. This is a clear example (statistics of more than 50 particles were made) of a case where crystals grow toward the light. It was observed (80) that precipitation takes place on those sides of glass windows of a vessel with fast sublimizing substances such as camphor and iodine, where the light comes in and not as should be expected on the darker and thus colder walls which were protected from the light. *This indicates that the photophoretic force is not due to heating effects.* This should be of interest to mineralogists.

6. The Ponderomotive Forces upon Matter.

If light induces electric and magnetic charges upon matter and if as under the conditions of the experiments, there are also electric and magnetic fields in beams of light (57) besides the well-known oscillating ones it follows that there are ponderomotive forces besides the light pressure which are produced by those stationary components and induced charges. *These forces have attracting as well as repelling effects.*

V. CONCLUSION.

Particles of matter irradiated by light between electrodes behave as if they carry positive or negative electric charges. Therefore we can say that through the action of the light uncharged particles obtain unipolar charges, either negative or positive.

Particles of matter, sufficiently irradiated by light between

magnetrodes behave as if they carry single south or north magnetic poles (charges). Light therefore produces unipolar magnets (magnetic ions, charges). Unipolar particles flow in homogeneous fields E or H in the direction of the field and reverse their movement with the field. Such a flow of particles simultaneously in both directions can be observed directly by means of a microscope (dark field). One can actually see the flow of an electric current in the above mentioned arrangement. It is very remarkable that the same picture appears if the magnetic field is applied as if the electric field is applied. From the visual appearance it is impossible to determine when an electric and when a magnetic field is applied. The generality of this effect is not diminished by the necessity of using light to produce magnetic ions. It will be a question of further investigation to find out if magnetic ions exist also without light. It should be remembered that when electric currents were discovered, dissociation in the voltaic cell was considered all important, but nobody could explain it. No model to picture what happens in a voltaic cell was known to aid ones imagination and in the same way the author does not attempt to use a model to explain the mechanism of the production of the magnetic ions. . . .

It is evident that a great number of problems are suggested by the conclusions described above. Thus, for instance, one may think of the existence of conductors of magnetic ions, of the heat created by the flow of magnetic ions, etc.

In this paper, the attempt has been made to show that a beam of light causes or induces not only heat and electricity but also magnetism at the same time.

Although an attempt has been made to separate the thermal and mechanical forces from the electric and magnetic ones one cannot be certain, from a general point of view, whether this is entirely possible in the observation of physical phenomena.

NOTE MADE WHILE CORRECTING THE PAPER (DECEMBER 14, 1941).

THE PERMANENT MAGNETIC ION.

The author succeeded recently together with Dr. Leo Banet to observe magnetic ions (single magnetic poles, magnetic charges) which were not created by light.

(1) In a completely homogeneous vertical condenser particles of finest iron powder move from the center of one Magnetrode to the center of the other one, while one part of the particles is at rest.

(2) Colloidal nickel particles which were suspended in water move in the dark between homogeneous (gold plated) Magnetrodes of iron in such a way that one part goes to the North and one part to the South Magnetrode. There is a *Magnetophoresis* in the dark.

The deposits could also be preserved in a number of cases on photographic plates.

Further facts will be reported later.

It seems clear that the above described magnetic ions which were created by light represent only a special case of the "Magnetic Ions" in general.

Acknowledgment.

I wish to thank: The Rockefeller Foundation for a grant which enabled me to do a great deal of this research work in my former laboratory in Vienna. My former pupil, now friend and co-worker, Dr. Leo Banet for his kind coöperation in writing this paper and suggestions made in connection with it. My dear friend, Prof. of internal medicine, John Plesch (London) and Prof. of orthopedic surgery Arthur Steindler (Iowa City) for facilitating continuation of my scientific work after I was forced to leave my institute and home in Vienna. Most of all the sculptress, Mrs. Lilly Rona (New York, N. Y.) at whose hospitable summer home I found the stimulation and calmness to work on this paper.

350 WEST 58TH STREET,
NEW YORK, N. Y.,
March, 1941.

REFERENCES.

(* indicates the papers which were written by the author and his pupils.)

* 1. EHRENHAFT (F.). *Wiener Berichte*, **119** (II *a*) (1910), 836.
* 2. EHRENHAFT (F.). *Phys. Ztschrft.*, **15** (1914), 608.
* 3. EHRENHAFT (F). *Wiener Akad. Anz.*, **11** (7 mai 1914), 4 (3 fev. 1916).
* 4. EHRENHAFT (F.). *Phys. Ztschrft.*, **18** (1917), 352.
* 5. EHRENHAFT (F.). *Ann. der Phys.*, **56** (1918), 81.
* 5*a*. EHRENHAFT (F.). *C. R.*, **182** (1926), 1138; *Phys. Zeitschr.*, **27** (1926), 859.
* 6. EHRENHAFT (F.). *Philos. Mag.*, **11** (1931), 140.

* 7. EHRENHAFT (F.). *C. R.*, **190** (1930), 263.
* 7*a*. EHRENHAFT (F.). *Phil. Mag.*, **11** (1931), 140.
* 8. EHRENHAFT (F.). *Phys. Ztschrft.*, **31** (1930), 478.
* 8*a*. EHRENHAFT (F.). *Phys. Ztschrf.*, **33** (1932), 673.
* 9. EHRENHAFT (F.). *In: Congr. Intern. Phys. Chim. Biol.*, Paris (1937).
*10. EHRENHAFT (F.). *Phys. Ztschrft.*, **39** (1938), 673.
*11. EHRENHAFT (F.). *Phys. Ztschrft.*, **33** (1932), 673.
*12. EHRENHAFT (F.) ET KONSTANTINOWSKI (D.). *Wiener Akad. Anz.*, **11** (18 mars 1920).
*13. EHRENHAFT (F.), REISS (M.) ET WASSER (E.). *Ztschrft. f. Phys.*, **60** (1930), 754; **67** (1931), 519.
*14. EHRENHAFT (F.) ET WASSER (E.). *Ztschrft. f. Phys.*, **40** (1926), 42.
*15. PARANKIEWICZ (I.). *Ann. der Phys.*, **57** (1918), 489; *Wiener Akad. d. Wiss.* (II *a*), 127 (1918), 1445.
16. MICHAUD (F.). *C. R.*, **168** (1919), 770.
17. EPSTEIN (P.). *Mitt. Phys. Ges. Zurich*, **19** (1919), 30.
18. TERADA (T.). *Proc. Phys. Math. Soc. Japan* (3), **4** (1922), 67.
19. GERLACH (W.) ET WESTPHAL (W.). *Verh. Ds. Phys. Ges.*, **21** (1919), 218.
20. WESTPHAL (W.). *Ztschrft. f. Phys.*, **1** (1920), 92, 256, 431; **4** (1921), 222.
21. GERLACH (W.). *Ztschrft. f. Phys.*, **2** (1920), 207.
22. RUBINOWICZ (A.). *Ann der Phys.*, **62** (1920), 691, 716.
23. RUBINOWICZ (A.). *Ztschrft. f. Phys.*, **6** (1921), 405.
24. RUBINOWICZ (A.). *Ztschrft. f. Phys.*, **35** (1926), 540.
*25. LASKI (G.) ET ZERNER (F.). *Ztschrft. f. Phys.*, **3** (1920), 224.
*25*a*. SATYENDRA RAY. *Ann. der Physik.* (4), **66** (1921), 71.
*26. LASKI (G.) ET ZERNER (F.) *Ztschrft. f. Phys.*, **6** (1921), 411.
*27. MATTAUCH (I.). *Wiener Akad. Ber.*, **129** (II *a*) (1920), 867.
*28. MATTAUCH (I.). *Phys. Ztschrft.*, **23** (1922), 444.
*29. MATTAUCH (I.). *Ann. der Phys.*, **85** (1928), 967.
30. HETTNER (G.). *Ztschrft. f. Phys.*, **27** (1924), 12.
30*a*. PATTERSON (S.) AND WHYTLAW GRAY (R.). *Proc. Leeds Philosoph. Lit. Soc. Scient.*, Sect. 1 (1926), 70.
*31. SEXL (Th.). *Ztschrft. f. Phys.*, **52** (1928), 249.
32. HALPERN (O.). *Ann. der Phys.*, **73** (1924), 457.
33. HETTNER (G.). *Ztschrft. f. Phys.*, **37** (1926), 179.
34. SATYENDRA RAY. *Koll. Ztschrft.*, **45**, Heft 1 (1928).
*34*a*. BRINGS (TH.). *Zeitschrft. f. Phys.*, **60** (1929), 759.
35. BARKAS (W. W.). *Philos. Mag.*, **2** (1926), 1019; **9** (1930), 505.
36. FACHINI (G.). *Koll. Ztschrft.*, **56** (1931), 40.
*37. PLACZEK (G.). *Ztschrft. f. Phys.*, **49** (1928), 601.
*38. SELNER (P.). *Ztschrft. f. Phys.*, **71** (1931), 658.
*39. REEGER (E.). *Ztschrft. f. Phys.*, **71** (1931), 646.
*40. WILFLINGER (E.). *Ztschrft. f. Phys.*, **71** (1931), 666.
*41. LUSTIG (A.) ET SOLLNER (A.). *Ztschrft. f. Phys.*, **79** (1932), 823.
42. WHYTLAW-GRAY (R.) ET PATTERSON (H. S.). "Smoke, A Study of Aerial Disperse Systems," London, Edward Arnold and Co. (1932).
*43. ISSER (G.) ET LUSTIG (A.). *Ztschrft. f. Phys.*, **96** (1935), 760.
*44. REISS (M.). *Phys. Ztschrft.*, **36** (1935), 410.

*45. CASTELLIZ (H.). *Ztschrft. f. Phys.*, **94** (1935), 677; **98** (1935), 536.
*46. GROTZINGER (G.). *Phys. Ztschrft.*, **38** (1937), 766.
47. DEBYE (P). *Ann. der Phys.*, **30** (1909), 57.
48. SCHWARZSCHILD (K.). *Munchner Ber.*, **31** (1902), 293.
*49. ZERNER (F.). *Phys. Ztschrft.*, **20** (1919), 93.
50. BREDICHIN. S. Petersbourg (1903).
51. LEBEDEW (P.). *Astr. Ges.*, S. Petersbourg, **37** (1902), 220.
*52. REISS (M.). *Physik Zeitschr.*, **33** (1932), 185.
*53. EHRENHAFT (F.). *Ann. de Phys.*, **13** (1940), 151.
*54. EHRENHAFT (F.). *Phys. Zeitschrft.* **39** (1938), 685.
*55. EHRENHAFT (F.). *Phys. Rev.*, **57** (1940), 562, 659. Also *Phys. Rev.*, June 1, 1940.
*56. EHRENHAFT (F.). JOUR. FRANK. INST., Sept. 1940, 381.
*57. EHRENHAFT (F.). Stationary electric and magnetic fields in beams of light. Letter to the Ed. of *Nature*, London. Jan. 4, 1941, p. 25.
*58. EHRENHAFT (F.) AND BANET (L.). The Magnetization of Matter by Light. Letter to the Editor of *Nature*, London, Vol. 147, p. 297, March 8, 1941.
*59. F. EHRENHAFT AND L. BANET. "Is There True Magnetism Or Not?" *Philos. of Science*, **8**, No. 3, 1941.
*60. EHRENHAFT (F.). *Wiener Berichte*, **116** (II *a*), 1907, 1175.
61. PEREGRINUS (P.). De magnete, etc. Chapter V. Letter of August 12. anno 1269.
62. NORMAN (R.). A New Attractive. Chapter VI. Anno 1576.
63. GILBERT (W.). "De Magnete," Book IV, Chapter VI, anno 1628.
64. JOFFE (A.). *Ber. Bayr. Ak. Muenchen*, 1913, 19.
65. MEYER (E.) AND GERLACH (W.). *Ann. d. Phys.*, **45**, 1914, 177.
66. KELLY (M. I.). *Phys. Rev.*, **16**, 1920, 260.
67. LUCHSINGER (F.). *Archive science physique et nat.*, 1, 1919, 544.
*68. SCHARF (K.). *Zeitschr. f. Phys.*, **49**, 1928, 827.
*69. HAKE (M.). *Zeitschr. f. Phys.*, **15**, 1923, 110.
*70. WASSER (E.). *Zeitschr. f. Phys.*, **27**, 1924, 203.
71. MORICHINI (D.). *Gilberts' Ann. d. Phys.*, **45**, 1813, 212; **46**, 1814, 367.
72. SOMMERVILLE (M.). *Gilberts' Ann. d. Phys.*, **82**, 1826, 495.
73. ZANTEDESCHI (F.). *Gilberts' Ann. d. Phys.*, **92**, 1829, 187.
74. VON BAUMGARTNER. *Gilberts' Ann. d. Phys.*, **85**, 1827, 508.
75. RIESS (P.) AND MOSER (L.). *Gilberts Ann. d. Phys.*, **92**, 1829, 563.
*76. EHRENHAFT (F.). *Wiener Ber.*, 123 (II *a*), 1914, p. 54.
*77. EHRENHAFT (F.). *Phys. Zeitschrft.*, **15**, 1914, 953.
*78. EHRENHAFT (F.). *Ann. d. Phys.*, **56**, 1918, 1.
*79. See 55.
80. RAIKOW (P. N.). *Chemiker Zeit.*, 1902, 1030.
81. ALEXANDER (JER.). "Colloidchemistry," Vol. 1, 1926, p. 362.
82. EHRENHAFT (F.). "The Micro-Coulomb Experiment" (Charges Smaller Than The Electronic Charge). *Philosophy of Science*, **8**, no. 3, July 1941.
*83. EHRENHAFT (F.). *Science Wkly.*, **94**, 1941, 232.

THE RESPONSE OF A NETWORK TO AN ARBITRARY PERIODIC DRIVING FORCE.

BY

EDWIN W. HAMLIN,

The University of Texas, Austin, Texas.

A formula by which the response of a network to an arbitrary periodic force may be determined in closed form is developed by use of the Heaviside Expansion Theorem and Du Hamel's Integral. A tabulation of some of the force functions met in practice and their responses is given, and the formula applied to some simple problems.

INTRODUCTION.

The problem of obtaining the steady state response due to an arbitrary periodic force impressed on a passive linear network is usually attacked on the basis of Fourier analysis. The result of this process is in infinite series form, exhibiting the various harmonic components of the response. If the solution is desired in closed form, this series result may be summed. This is often difficult. Other methods require considerable knowledge of mathematical theory.

This paper presents in closed form a general solution of this problem. It is analagous to, and derived from, the Heaviside Expansion Theorem. The formula derived is, therefore, subject to the same limitations with regard to the network as is the Heaviside formula, but may be used with the same ease.

The result is useful whenever a knowledge of the actual wave shape is to be preferred to a knowledge of the harmonic content of the response. As applied to electrical problems, it is useful when power or root mean square value of the response is of importance. It gives a different approach to the phenomenon of resonance. It also forms a new way of developing summation formulae for Fourier Series results.

The general method has been used to advantage by C. W. Carnahan [1] in studying Television circuits.

DERIVATION OF FORMULA.

The formula for the response may be derived as follows: Let the period of the impressed force be given by T, and let time, t, be measured from an arbitrarily chosen point considered to be the beginning of a cycle. The interval T is divided into m parts, whose lengths are given by T_1, T_2, $\cdots T_m$. In each of these the force may be expressed as $e(u)$, where u is the time measured from the beginning of the

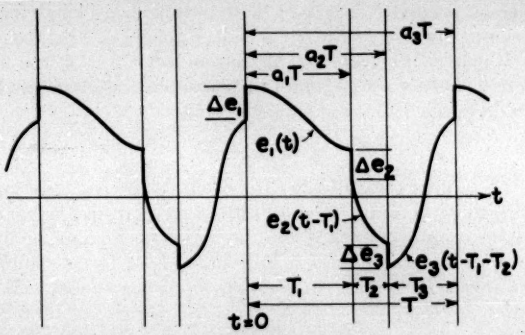

FIG. 1. Arbitrary driving force.

interval in which $e(u)$ acts. In what follows, it will be assumed that the force may be expressed completely by using only three intervals. The extension to m intervals will be apparent.

The forces acting near $t = 0$ are as shown in Fig. 1. The response of the network during the time interval $0 < t < T$, will be due not only to $e_1(t)$, but to all the forces which have acted prior to $t = 0$.

At $t = 0$, $e_1(t)$ is impressed, and this is the only force acting from $t = 0$ to $t = T_1$. But immediately prior to $t = 0$, $e_3(t + T_3)$ was acting. At $t = 0$, this force must cease to act. This effect may be brought about analytically by

[1] "Network Response and Application to Television," C. W. Carnahan, *Proc. I. R. E.*, 23, No. 11, November, 1935, p. 1393.

considering that at this time two forces are brought into action, $e_1(t)$, and $-e_3(t + T_3)$. Also, in the interval immediately preceding $t = 0$, $e_3(t + T_3)$ was the only force acting, and so at $t = -T_3$, two forces, $e_3(t + T_3)$ and $-e_2(t + T_2 + T_3)$, will give the proper result. The response at $t = 0$, valid in the interval $0 < t < T_1$, will, then, be given by the response to

$$\left.\begin{array}{ll} e_1(t) & \text{impressed at } t = 0 \\ -e_3(t + T_3) & \text{" " } t = 0 \\ e_3(t + T_3) & \text{" " } t = -T_3 \\ -e_2(t + T_2 + T_3) & \text{" " } t = -T_3 \\ e_2(t + T_2 + T_3) & \text{" " } t = -(T_2 + T_3) \\ -e_1(t + T) & \text{" " } t = -(T_2 + T_3) \\ e_1(t + T) & \text{" " } t = -T \\ -e_3(t + T + T_3) & \text{" " } t = -T \\ e_3(t + T + T_3) & \text{" " } t = -(T + T_3) \end{array}\right\} \begin{array}{l} (a') \\ \\ (b') \\ \\ (c') \\ \\ (a'') \end{array} \qquad (1)$$

and so on.

Assume that the "indicial admittance" of the network to which this force function is applied is given by $A(t)$. Then the response to a force $e(t)$ impressed at $t = 0$ may be written by the superposition theorem as

$$i(t) = e(0)A(t) + \int_0^t e'(\lambda)A(t - \lambda)d\lambda, \quad t > 0, \quad (2)^{2,3}$$

where

$$e'(\lambda) = \frac{d}{d\lambda} e(\lambda) \cdot$$

Also impressing $e(t + \alpha)$ at $t = -\beta$, $(\beta < \alpha)$, gives

$$i_1(t) = e(\alpha - \beta)A(t + \beta) + \int_0^{t+\beta} e'(\lambda - \beta + \alpha)A(t + \beta - \lambda)d\lambda, \quad t > -\beta.$$

By changing the variable of integration, this may be written as

$$i_1(t) = e(\alpha - \beta)A(t + \beta) + \int_{-\beta}^t e'(\lambda + \alpha)A(t - \lambda)d\lambda, \quad t > -\beta. \quad (3)$$

[2] "Heaviside's Operational Calculus," E. J. Berg, McGraw-Hill Book Company, New York, 1936, p. 67.

[3] "Operational Circuit Analysis," V. Bush, John Wiley and Sons, New York, 1929, p. 56.

From (3) it is apparent that the response due to $e(t+\alpha)$ impressed at $t=-\alpha$, and removed (by impressing $-e(t+\alpha)$ at $t=-\beta$) will be given by

$$i_2(t) = e(0)A(t+\alpha) - e(\alpha-\beta)A(t+\beta) + \int_{-\alpha}^{-\beta} e'(\lambda+\alpha)A(t-\lambda)d\lambda,$$

and by further change of the variable of integration,

$$i_2(t) = e(0)A(t+\alpha) - e(\alpha-\beta)A(t+\beta) + \int_{0}^{\alpha-\beta} e'(\lambda)A(t+\alpha-\lambda)d\lambda, \quad t > -\beta. \quad (4)$$

Now, with the exception of $e_1(t)$, the whole force function, (1), is made up of pairs of terms which will give a result similar to (4). The grouping is indicated by the brackets in the set, (1). From (4), the response due to the pair (a'), given by identifying α with T_3 and β with zero, will be

$$i_{a'}(t) = e_3(0)A(t+T_3) - e_3(T_3)A(t) + \int_{0}^{T_3} e_3'(\lambda)A(t+T_3-\lambda)d\lambda, \quad t > 0. \quad (5)$$

In the same way, due to the pair (a''),

$$i_{a''}(t) = e_3(0)A(t+T+T_3) - e_3(T_3)A(t+T) + \int_{0}^{T_3} e_3'(\lambda)A(t+T+T_3-\lambda)d\lambda, \quad t > 0. \quad (6)$$

Similarly the result for the other e_3 terms may be written. These may be summed in a series, giving

$$i_a(t) = \sum_{\kappa=0}^{\infty}\left[e_3(0)A(t+\kappa T+T_3) - e_3(T_3)A(t+\kappa T) + \int_{0}^{T_3} e_3'(\lambda)A(t+\kappa T+T_3-\lambda)d\lambda\right]. \quad (7)$$

The result obtained for the pairs of e_1 and e_2 terms may be written in the same manner. Let these be $i_b(t)$ and $i_c(t)$.

Now the Heaviside Expansion Theorem may be expressed as

$$A(t) = \frac{1}{Z(0)} + \sum_{r=1}^{S} \frac{\epsilon^{p_r t}}{p_r Z'(p_r)} = \frac{1}{Z(0)} + \sum_{r=1}^{S} H_r \epsilon^{p_r t}, \qquad (8)$$

where $A(t)$ is the indicial admittance, as above, $Z(p)$ is the impedance operator of the network, and the summation is extended over the S roots of $Z(p) = 0$. Upon substituting (8) in (7) all terms involving $1/Z(0)$ cancel out, and $A(t)$ may be replaced by $\sum H_r \epsilon^{p_r t}$. This summation is a finite one, and the sum indicated in (7) may be carried out for each of its terms separately. Considering the general term, (7) becomes

$$H_r \epsilon^{p_r(t+T_3)} \Big[e_3(0) - e_3(T_3)\epsilon^{-p_r T_3} + \int_0^{T_3} e_3'(\lambda)\epsilon^{-p_r \lambda} d\lambda \Big] \sum_{s=0}^{\infty} \epsilon^{p_r s T}. \qquad (9)$$

The sum indicated in (9) is a geometric series, and is convergent since in a physical network p_r will have a negative real part. Its value is $1/(1 - \epsilon^{p_r T})$. Then

$$i_a(t) = \sum_{r=1}^{S} \frac{H_r \epsilon^{p_r(t+T_3)}}{1 - \epsilon^{p_r T}} D(e_3, T_3), \qquad (10)$$

where $D(e_3, T_3)$ means the bracketed terms in (9). In the same way it may be shown that the response due to terms (b'), (b''), etc. of (1) is

$$i_b(t) = \sum_{r=1}^{S} \frac{H_r \epsilon^{p_r(t+T_2+T_3)}}{1 - \epsilon^{p_r T}} D(e_2, T_2), \qquad (11)$$

and due to terms (c'), (c''), etc.,

$$i_c(t) = \sum_{r=1}^{S} \frac{H_r \epsilon^{p_r(t+T)}}{1 - \epsilon^{p_r T}} D(e_1, T_1). \qquad (12)$$

The response due to all forces impressed before $t = 0$ will be the sum of these three. To these must be added the result of applying $e_1(t)$ at $t = 0$. Then the whole solution, valid

in the interval $0 < t < T_1$ is

$$i(t) = i_a(t) + i_b(t) + i_c(t) + e_1(0)A(t) + \int_0^t e_1'(\lambda)A(t-\lambda)d\lambda. \quad (13)$$

Substituting (8) in the last two terms of (13), the terms which involve both $Z(0)$ and $e_1(0)$ cancel, leaving

$$\frac{e_1(t)}{Z(0)} + \sum_{\nu=1}^{S} H_\nu \epsilon^{p_\nu t} \int_0^t e_1'(\lambda)\epsilon^{-p_\nu\lambda}d\lambda + \sum_{\nu=1}^{S} H_\nu \epsilon^{p_\nu t} e_1(0). \quad (14)$$

The whole result may now be written as the sum of (10), (11), (12), and (14). The last term in (14) may be included with the $e_1(0)$ term in $i_c(t)$.

It is now possible to write, in fairly compact form, the general result for the case of m time intervals in one period. To do this, let the first two terms in (14) be represented by $B(t)$, that is

$$B(t) = \frac{e_1(t)}{Z(0)} + \sum_{\nu=1}^{S} H_\nu \epsilon^{p_\nu t} \int_0^t e_1'(\lambda)\epsilon^{-p_\nu\lambda}d\lambda. \quad (15)$$

Also, let $a_\kappa T = T_1 + T_2 + \cdots + T_\kappa$, $a_0 T = 0$; and let $\Delta e_\kappa = e_{\kappa+1}(0) - e_\kappa(T_\kappa)$ that is, let Δe_κ be the instantaneous rise of the force function at $t = a_{\kappa-1}T$. See Fig. 1. Then the solution, valid in the interval $0 < t < T_1$ is given by

$$i(t) = B(t) + \sum_{\nu=1}^{S} \frac{H_\nu \epsilon^{p_\nu(t+T)}}{1 - \epsilon^{p_\nu T}} \times \sum_{\kappa=1}^{m} \left(\epsilon^{-p_\nu a_\kappa T}\Delta e_\kappa + \epsilon^{-p_\nu a_{\kappa-1}T} \int_0^{T_\kappa} e_\kappa'(\lambda)\epsilon^{-p_\nu\lambda}d\lambda \right). \quad (16)$$

It would be possible to write the response for the interval $T_1 < t < T_2$ as well, but this is unnecessary. A simple shift of the time axis makes (16) applicable to the other intervals.

This result may be simplified for ready use for many of the common force functions met in practice. For instance, if the force function is the rectangular one of Fig. 2, $e_1(t) = E$, $e_2(t - T_1) = -E$, $e_\kappa'(\lambda) = 0$, $\Delta e_1 = -2E$, $\Delta e_2 = 2E$,

$T_1 = T/2$, $a_1 = 1/2$, $a_2 = 1$, and the response for the interval $0 < t < T/2$ will be

$$i(t) = \frac{E}{Z(0)} + 2E \sum_{\nu=1}^{S} \frac{H_\nu \epsilon^{p_\nu T}}{1 + \epsilon^{p_\nu T/2}}. \tag{17}$$

From $t = T/2$ to $t = T$, (17) will repeat, but with a negative sign.

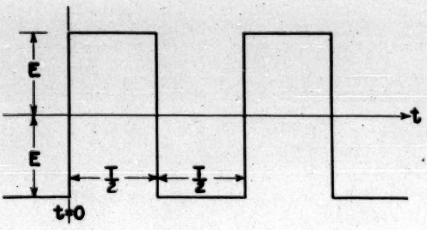

FIG. 2. Rectangular force function.

Other force functions and their responses are shown in the following tabulation.

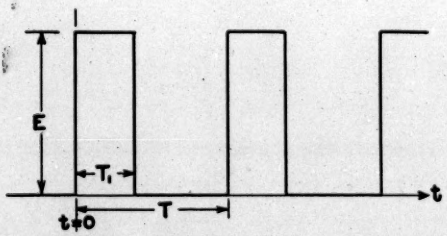

FIG. 3. Force function whose response is given by (18).

$$\left.\begin{aligned} i(t) &= \frac{E}{Z(0)} + E \sum_{\nu=1}^{S} H_\nu \frac{1 - \epsilon^{p_\nu (T - T_1)}}{1 - \epsilon^{p_\nu T}} \epsilon^{p_\nu t}, \quad 0 < t < T_1, \\ i(t) &= E \sum_{\nu=1}^{S} H_\nu \frac{1 - \epsilon^{p_\nu T_1}}{1 - \epsilon^{p_\nu T}} \epsilon^{p_\nu t}, \qquad\qquad T_1 < t < T, \end{aligned}\right\} \tag{18}$$

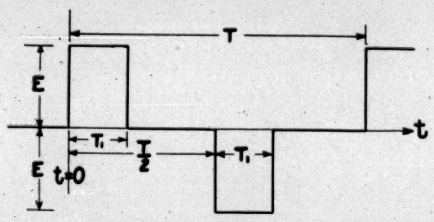

FIG. 4. Force function whose response is given by (19).

$$\left.\begin{aligned} i(t) &= \frac{E}{Z(0)} + E\sum_{\nu=1}^{S} H_\nu \frac{1+\epsilon^{p_\nu[(T/2)-T_1]}}{1+\epsilon^{p_\nu T/2}}\epsilon^{p_\nu t}, \quad 0 < t < T_1, \\ i(t) &= E\sum_{\nu=1}^{S} H_\nu \frac{1-\epsilon^{-p_\nu T_1}}{1+\epsilon^{p_\nu T/2}}\epsilon^{p_\nu t}, \qquad\qquad T_1 < t < T/2. \end{aligned}\right\} \quad (19)$$

Values repeat with negative signs in interval $T/2 < t < T$.

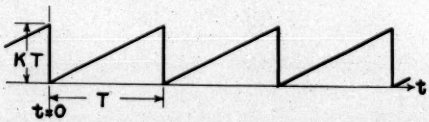

FIG. 5. Force function whose response is given by (20).

$$i(t) = \frac{Kt}{Z(0)} - K\sum_{\nu=1}^{S} H_\nu\left(\frac{1}{p_\nu} + \frac{T\epsilon^{p_\nu t}}{1-\epsilon^{p_\nu T}}\right), \quad 0 < t < T, \quad (20)$$

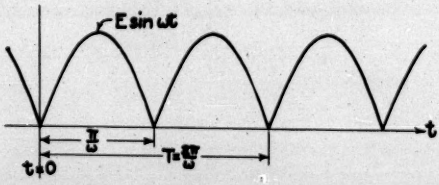

FIG. 6. Single phase half wave rectifier output whose response is given by (21).

$$i(t) = \text{s.s.}\,[E\sin\omega t] - E\sum_{\nu=1}^{S} H_\nu \frac{\sin 2\varphi}{1-\epsilon^{p_\nu\pi/\omega}}\epsilon^{p_\nu t}, \quad 0 < t < \frac{\pi}{\omega}, \quad (21)$$

where s.s. $[E \sin \omega t]$ means the steady state response of the network to $E \sin \omega t$ and $\tan \varphi = \omega/(-p_r)$.

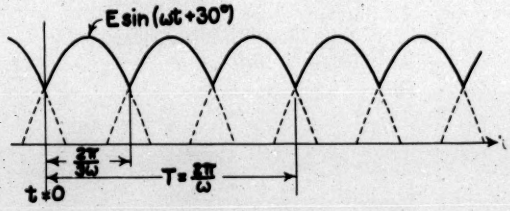

FIG. 7. Three phase half wave rectifier output whose response is given by (22).

$$i(t) = \text{s.s. } [E \sin (\omega t + 30°)] - \frac{\sqrt{3}}{2} E \sum_{r=1}^{s} H_r \frac{\sin 2\varphi}{1 - \epsilon^{2\pi p_r/3\omega}} \epsilon^{p_r t}, \quad 0 < t < \frac{2\pi}{3\omega}, \quad (22)$$

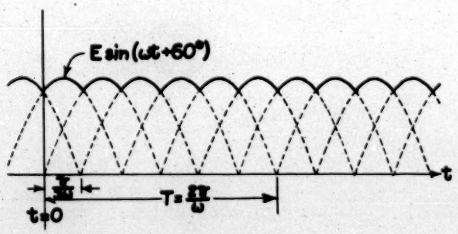

FIG. 8. Three phase full wave rectifier output whose response is given by (23).

$$i(t) = \text{s.s. } [E \sin (\omega t + 60°)] - \frac{E}{2} \sum_{r=1}^{s} H_r \frac{\sin 2\varphi}{1 - \epsilon^{p_r \pi/3\omega}} \epsilon^{p_r t}, \quad 0 < t < \frac{\pi}{3\omega}. \quad (23)$$

Formulas (18) and (20) are also given by Carnahan.[1]

APPLICATION TO SIMPLE PROBLEMS.

As a simple application of these results, the following problem will be solved. A battery of e volts is to be charged by an ideal full wave single phase rectifier, supplied from a

source whose voltage is given by $E \sin \omega t$, through a coil whose inductance is L, and whose resistance is R. The current is to be found.

Formula (21) applies, except that e/R must be subtracted from the result. (This is true on the assumption that the inductance is large enough to make the current continuous. If it is not, then a simple transient solution may be used.) Then $\tan \varphi = \omega L/R$, $p_1 = -R/L$, $H_1 = -1/R$, and the current is

$$i = \frac{E}{Z}\left[\sin(\omega t - \varphi) + \frac{2 \sin \varphi \epsilon^{-(R/L)t}}{1 - \epsilon^{-R\pi/\omega L}}\right] - \frac{e}{R}, \qquad (24)$$

where $Z = \sqrt{R^2 + \omega^2 L^2}$. This result is valid in the interval $0 < t < \pi/\omega$, and gives a much better idea of the actual wave shape than the corresponding Fourier series solution, which is

$$i = \frac{2E}{\pi R} - \frac{4E}{\pi} \sum_{n=1}^{\infty} \frac{\cos(2n\omega t - \varphi_{2n})}{(4n^2 - 1)\sqrt{R^2 + (2n\omega L)^2}} - \frac{e}{R},$$

$$\text{where } \tan \varphi_{2n} = \frac{2n\omega L}{R}. \qquad (25)$$

It should be noticed that (24) is the sum of the series (25). The current plotted from (24), for $E = 200$, $e = 100$, $R = 10$, $\omega L = 40$, is shown in Fig. 9.

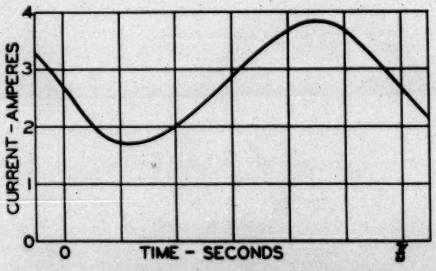

FIG. 9. Battery charging current.

The average current, from (24), will be $\frac{\omega}{\pi}\int_0^{\pi/\omega} i\,dt$. Upon

performing the integration, this reduces to $i_{av} = \frac{2E}{\pi R} - \frac{e}{R}$, which agrees with the result apparent from the series solution.

As a further example, the response of an oscillatory series circuit of resistance, R, inductance, L, and capacitance, C, to the rectangular voltage wave of Fig. 2, will be determined. Only one-half of a cycle need be considered, since the current values will repeat with negative signs in the next half cycle. Applying (17) with $T = 2\pi/\omega$, since $Z(p) = R + Lp + 1/Cp$, $Z(0)$ becomes infinite, $H_r = \frac{1}{2p_rL + R}$, and the two values of p_r are $p_1 = -\alpha + j\beta$, and $p_2 = -\alpha - j\beta$, where $\alpha = \frac{R}{2L}$, and $\beta = \sqrt{\frac{1}{CL} - \alpha^2}$. Then the current becomes

$$i = 2E \sum_{r=1}^{2} \frac{\epsilon^{p_r t}}{(2p_rL + R)(1 + \epsilon^{p_r \pi/\omega})}. \qquad (26)$$

Putting in the values of p, and combining terms, this may be written

$$i = \frac{2E\epsilon^{-\alpha t}}{\beta L\sqrt{x^2 + y^2}} \sin(\beta t - \theta), \quad 0 < t < \frac{\pi}{\omega}, \qquad (27)$$

where $x = 1 + \epsilon^{-\alpha\pi/\omega} \cos\frac{\beta\pi}{\omega}$, $y = \epsilon^{-\alpha\pi/\omega} \sin\frac{\beta\pi}{\omega}$, and $\tan\theta = \frac{y}{x}$.

The Fourier series for the impressed voltage is

$$e = \frac{4E}{\pi} \sum_{n=1}^{\infty} \frac{\sin(2n-1)\omega t}{2n-1},$$

from which the current may be written as

$$i = \frac{4E}{\pi} \sum_{n=1}^{\infty} \frac{\sin[(2n-1)\omega t - \varphi_{2n-1}]}{(2n-1)Z_{2n-1}}, \qquad (28)$$

where $x_n = n\omega L - \frac{1}{n\omega C}$, $Z_n = \sqrt{R_n^2 + x_n^2}$, and $\tan\varphi_n = x_n/R$. Equation (27) is a summation formula for the Fourier series, (28). That the two are equivalent may be shown most easily by developing the Fourier series for (27), which will give (28).

In (28) resonance is said to occur when some reactance, x_n, becomes zero. The nth harmonic response is then seen to be large compared to the other harmonics. In the repeated transient solution, (27), resonance occurs when β, the natural angular velocity of the circuit, becomes equal to an odd multiple of ω, the fundamental angular velocity of the rectangular impressed voltage. When this happens x becomes $1 - \epsilon^{-\alpha\pi/\omega}$, which is small if R is small, y equals zero, and the current becomes large.

Suppose the circuit to be tuned to the fifth harmonic of the impressed voltage. By the Fourier solution, a fifth harmonic will be the predominant feature of the current. It is difficult to say, however, what the actual wave shape will be. Using the repeated transient solution, if $\beta = 5\omega$,

$$i = \frac{2E\epsilon^{-\alpha t} \sin 5\omega t}{5\omega L(1 - \epsilon^{-\alpha\pi/\omega})}, \tag{29}$$

and the shape of the wave is immediately apparent. This result brings out the fact that the current will oscillate at the

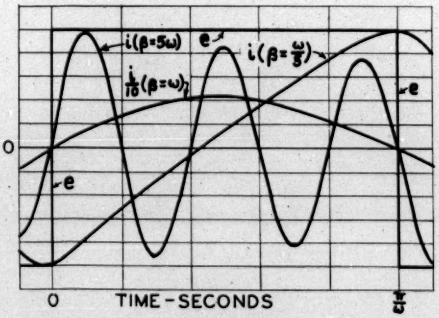

FIG. 10. Response of an oscillatory circuit tuned to frequency $\beta/2\pi$ to the rectangular voltage wave shown.

natural frequency of the circuit, regardless of the period of the impressed voltage. However, if the impressed frequency is greater than the natural frequency of the circuit, the natural frequency is masked by the sudden reversal of voltage before

a cycle of natural frequency has been completed. Fig. 10 shows currents for various relative frequencies.

Average power may be obtained from the current and voltage, or from the current and resistance:

$$P = \frac{\omega}{\pi}\int_0^{\pi/\omega} Eidt = \frac{\omega}{\pi}\int_0^{\pi/\omega} i^2 Rdt.$$

In this case the first integral is more easily evaluated, and may be written as

$$P = \frac{\omega}{\pi}\int_0^{\pi/\omega} \frac{2E^2}{\beta L\sqrt{x^2+y^2}}\,\epsilon^{-\alpha t}\sin(\beta t - \theta)dt$$

$$= \frac{2E^2\omega C}{\pi\beta}\sqrt{\frac{x_1^2+y^2}{x^2+y^2}}\sin(\theta+\theta_1-\varphi), \qquad (30)$$

where $x_1 = 1 - \epsilon^{-\alpha\pi/\omega}\cos\frac{\beta\pi}{\omega}$, $\tan\theta_1 = \frac{y}{x_1}$ and $\tan\varphi = \frac{\beta}{\alpha}$.

Effective, or r.m.s., current may be obtained from the power.

This form of result for power is perhaps the easiest for numerical calculation. Power may be found, however, in a more compact form. The current may be written as

$$i = 2\mathbf{Re}\left[\frac{E\epsilon^{p_1 t}}{j\beta L(1-\epsilon^{p_1\pi/\omega})}\right],$$

where $p_1 = -\alpha + j\beta$, and "**Re**" indicates that the real part of the expression following shall be taken. The instantaneous power is Ei, and the average power will be

$$P = 2\mathbf{Re}\left[-\frac{E^2\omega(1-\epsilon^{p_1\pi/\omega})}{j\pi\beta L p_1(1+\epsilon^{p_1\pi/\omega})}\right]$$

$$= 2\mathbf{Re}\left[\frac{E^2\omega}{j\pi\beta L p_1}\tanh\frac{\pi p_1}{2\omega}\right].$$

This may also be written as

$$\frac{2E^2\omega}{\pi\beta L}\,\mathbf{Im}\left[\frac{\tan\frac{\pi q}{2\omega}}{q}\right],$$

where $q = \beta + j\alpha$, and "**Im**" indicates that the imaginary part of what follows is to be taken. In this form it has been found previously by use of summation formulae.[4]

CONCLUSION.

The chief advantage of this method is that it gives a solution in closed form. It should be emphasized that the result is the same as that obtained from the Fourier series, and gives a method of summing the series. Its chief disadvantage is inherent in any method employing the Heaviside Expansion Theorem. If the number of roots of the determinantal equation is large, the labor of determining them is large, and a general solution with roots determined explicitly is impossible.

The examples will perhaps serve to indicate the field of usefulness of the method. To obtain the result shown in Fig. 9 from equation (25) a summation formula for the series must be found, or the series must be summed numerically for a particular case. Plotting from the closed form (24) is, however, relatively simple. The same is true with regard to equations (28) and (27), plotted in Fig. 10.

In the rectifier problem, the average current is more easily determined from the Fourier solution. In the resonant circuit case, however, the power and effective current are more easily determined from (30) than from (28). Solution by this method, then, should complement that by Fourier series.

[4] "Communication Networks," Vol. I, E. A. Guillemin, John Wiley and Sons, New York, 1936, p. 420.

NOTES FROM THE NATIONAL BUREAU OF STANDARDS.*

REVISED STANDARD FREQUENCY BROADCASTS.

The standard frequency service of the Bureau's station WWV has been extended to include another carrier frequency (15 megacycles). The broadcast is continuous from 1-kilowatt transmitters, and carries the standard musical pitch and other features. The radio frequencies are:

5 megacycles (= 5,000 kilocycles = 5,000,000 cycles) per second.
15 megacycles (= 15,000 kilocycles = 15,000,000 cycles) per second.

The standard musical pitch is the frequency 440 cycles per second, corresponding to A above middle C. In addition, a pulse every second is heard as a faint tick when listening to the 440 cycles. The pulse lasts 0.005 second, and provides an accurate time interval for purposes of physical measurements.

The 440-cycle tone is interrupted every five minutes for one minute in order to give the station announcement and to provide an interval for checking radio measurements based on the standard radio frequency. The announcement is the station call letters (WWV) in telegraphic code (dots and dashes).

The accuracy of the 5- and 15-megacycle frequencies, and of the 440-cycle standard pitch as transmitted, is better than a part in 10,000,000. Transmission effects in the medium (Doppler effect, etc.) may result in slight fluctuations in the 440-cycle frequency as received at a particular place; the average frequency received is, however, as accurate as that transmitted. The time interval marked by the pulse every second is accurate to 0.000,01 second. The 1-minute, 4-minute, and 5-minute intervals, synchronized with the seconds

* Communicated by the Director.

pulses and marked by the beginning and ending of the announcement periods, are accurate to a part in 10,000,000. The beginnings of the announcement periods are so synchronized with the basic time service of the U. S. Naval Observatory that they mark accurately the hour and the successive 5-minute periods; this adjustment does not have the extreme accuracy of the time intervals, but is within a small fraction of a second.

In general, during the *winter* day, the 5-Mc. carrier frequency can be used at all distances out to about 1,000 miles and the 440-cycle tone out to about 700 miles; the 15-Mc. carrier frequency is usable from about 800 to 5,500 miles, and the 440-cycle tone from about 800 to 4,000 miles. During the *winter night*, i.e., between about 8 P.M. and 6 A.M. E.S.T., the 5-Mc. carrier frequency is usable from about 700 to 7,000 miles and the 440-cycle tone from about 700 to 5,000 miles; the 15-Mc. broadcast is not usable during the winter night, except for the short-distance ground wave (see below). During the *summer day*, the 5-Mc. carrier frequency is usable at all distances out to about 400 miles and the 440-cycle tone out to about 300 miles; the 15-Mc. carrier frequency is usable from about 900 to 3,000 miles and the 440-cycle tone from about 900 to 2,500 miles. During the *summer night* before midnight E.S.T., the 5-Mc. carrier frequency is usable out to about 2,500 miles and the 440-cycle tone out to about 1,400 miles, except for a period of 2 or 3 hours before sunrise when it is difficult to receive at distances between about 50 and 400 miles; the 15-Mc. carrier frequency is usable from about 1,000 to 7,000 miles and the 440-cycle tone from about 1,000 to 5,000 miles.

Besides the distances covered by the sky wave as just described, the ground wave provides coverage at short distances as follows. *At all times*, the 5-Mc. carrier frequency is usable out to about 100 miles and the 440-cycle tone out to about 50 miles; and the 15-Mc. carrier frequency is usable out to about 70 miles and the 440-cycle tone out to about 35 miles.

The service will be continuous except for such breakdowns as may possibly occur because of the use of temporary apparatus. Work is progressing as rapidly as possible on a

new station to provide more fully than in the past standard frequencies reliably receivable at all times throughout the country and adjacent areas.

ABSOLUTE DETERMINATION OF THE AMPERE.

In many types of measurements both electrical and mechanical units are involved. For instance, in a turbo-generator it is often necessary to measure the power input in terms of mechanical and thermal units and the power output in electrical units. In studying the efficiency of such a system it is important to be able to express all the measured quantities in terms of the units of one system. Fortunately, this principle was early realized, so that our electrical units are all based on the mechanical units of mass, length, and time. Values of electrical standards were established in terms of these mechanical units nearly three-quarters of a century ago. However, with improved methods of measurement a demand has arisen for a redetermination of the values of our electrical standards in terms of the mechanical units, giving them more accurate values than were possible by means of the earlier measurements. The result obtained when an extremely precise determination is made of an electrical quantity in terms of the mechanical units is called its absolute value.

For over 10 years, the Bureau has been engaged on determination of the values of its electrical standards in terms of the absolute values of the units. In the *Journal of Research* for February (RP1449), Roger W. Curtis, Raymond L. Driscoll, and Charles L. Critchfield describe their work on the standardization of the ampere. This was accomplished with an instrument known as a current balance in which the force of attraction between coils carrying electric currents is measured (*Technical News Bulletin* 265 (May, 1939)). The coils were made with extreme care and their dimensions were determined with high precision. The force is measured by comparing it with the gravitational force on a known mass by means of the sensitive balance. Using the measured dimensions and the force, the value of the current in absolute units can be computed. This same current is measured in

the international units, and thus a comparison between the two systems of units can be made. From such measurements it has been established that the absolute unit of current is larger by 150 parts in a million than the international unit.

INTERCOMPARISON OF PLATINUM RESISTANCE THERMOMETERS.

The fundamental scale of thermometry today for both scientific and industrial uses is the scale based on the two laws of thermodynamics which Lord Kelvin proposed in 1854. The establishment of this thermodynamic scale for accurate calibrations of practical thermometers requires very elaborate gas thermometers which are not generally available. Further, the precision attained with gas thermometers has not been as high as that more easily obtainable with other instruments and apparatus.

In 1927 in Paris, the International Committee on Weights and Measures, composed of representatives of the principal nations, proposed the International Temperature Scale as a more convenient and more precise method of calibrating thermometers than by comparison with gas thermometers. This scale reproduced the thermodynamic scale as accurately as the latter could then be established. This International Temperature Scale has been adopted by the principal standardizing laboratories of the world for scientific and industrial purposes. From $-190°$ to $+660°$ C. it is based upon the electrical resistance of a "strain-free" coil of "pure" platinum wire. The relation between the resistance, R, of platinum wire and temperature, t, on the International Scale is expressed by the equations:

(1) from 0° to 660° C.,

$$t° = \frac{R - R_0}{R_{100} - R_0} 100 + \delta \left(\frac{t}{100} - 1 \right) \frac{t}{100}$$

(2) from $-190°$ to 0°,

$$t° = \frac{R - R_0}{R_{100} - R_0} 100 + \delta \left(\frac{t}{100} - 1 \right) \frac{t}{100} + \beta \left(\frac{t}{100} - 1 \right) \frac{t^3}{100},$$

where R_0 and R_{100} are the resistances of the thermometer at the standard freezing and boiling points, respectively, of water, and δ and β are constants, the values of which are determined by calibrating the thermometer at the standard freezing point of water and the standard boiling points of water, sulphur, and oxygen. The numbers assigned to the temperatures of these calibration points in the definition of the scale are 0°, 100°, 444.6°, and − 182.97°.

It is impossible to obtain absolutely pure platinum wire and to mount any wire in an absolutely strain-free manner. The introduction of other substances as impurities in platinum, and residual strains influence the relation which exists between temperature and the resistance of the wire. Samples of platinum wire differing in purity and mechanical condition will give rise, therefore, to different scales of temperature just as different metals like nickel and platinum would be expected to do. This was realized when the International Temperature Scale was defined, and limits were placed upon the platinum coils which at the time were thought to be reasonable and yet stringent enough to insure good reproducibility of the scale. Until now, however, no investigation has been made to determine the differences between the scales of different thermometers that arise from the small variations in the platinum permitted by the scale.

Differences between the scales of different thermometers may arise in still another way, namely, from errors made in the calibration of thermometers at the ice, steam, sulphur, and oxygen points, either in the measurement of the resistances of the thermometers or in the establishment of standard conditions at the calibration points. Really these are not errors in the ordinary sense of the word because they arise from the practical limits of precision of calibration and not as a result of carelessness or oversight. Nevertheless, they should be taken into account in a determination of the effect of variations in impurities and strains in wire of different thermometers. This has been done in an investigation by Harold J. Hoge and Ferdinand G. Brickwedde, which is fully described in RP1454 in the *Journal of Research* for February.

Eight platinum resistance thermometers calibrated in ac-

cordance with the International Temperature Scale, all satisfying the requirements for purity and strain-free condition of the platinum, were compared at temperatures from − 190° to + 445° C. by measuring with each thermometer the temperature of a thermostated block of metal.

After minimizing the relative calibration errors, the maximum differences between readings of the seven best thermometers whose δ's in equations (1) and (2) ranged from 1.4936 to 1.4986, were 0.007 degree between − 190° and 0° C., and 0.001_3 degree between 0° and 100° C. Maximum differences from the mean were 0.004 and 0.000_8 degree respectively. For the eighth thermometer, whose δ was 1.5116, deviations from the mean of the other 7 were 0.015 at − 110° C. and 0.003 at + 50° C.

The results of this investigation may be used to determine more stringent limitations for the platinum of resistance thermometers in order to improve the reproducibility of the International Temperature Scale at low temperatures.

SPECTROGRAPHIC ANALYSIS OF COMMERCIAL TIN.

The Bureau analyzes samples of pig tin, tin pipe, tin-lined fittings, and fusible plugs for deleterious impurities under governmental specifications. Certain impurities seriously impair the effectiveness of tin products in use. For example, zinc or iron in amounts less than 1 per cent., or other elements in larger quantities, may raise the melting point of a fusible plug above the safety limit. Such a plug, designed for protection of boilers, may fail with resultant danger to life and property. Tin, one of the strategic elements, is not plentiful, and much reclaimed metal is finding its way back into use, adding to the importance of having rapid and reliable analytical methods. The wet-chemical analysis of tin is difficult and time-consuming when small amounts of impurities are involved. Bourdon F. Scribner of the Bureau's Spectroscopy Section, therefore, investigated the practicability of substituting a spectrographic method of analysis. A satisfactory method was developed, the procedure, which is described in detail in the February *Journal of Research* (RP1451), being as follows:

The tin is fabricated into electrode rods for spark excitation by (1) melting and chill-casting where mixing of the sample is required or (2) compressing millings or turnings of the sample under high pressure. The light from the spark between the tin electrodes illuminates a spectrograph which provides a photographic record of the spectrum. The intensities of selected impurity lines are measured relative to control lines of the tin spectrum by means of a photocell and galvanometer, incorporated in a microphotometer. The change of impurity-line intensity with concentration is measured for a series of samples of known composition, and a curve is drawn relating these quantities. The analysis of an unknown sample is made by measuring line intensities in the same manner and then reading the concentration from the analytical curve. The method permits determination of ten impurities: antimony, arsenic, bismuth, cadmium, copper, indium, iron, lead, silver, and zinc. The error is usually of the order of ± 5 per cent. of the amount present, and may be decreased to ± 2 per cent. by close control of conditions.

The time required for the necessary determinations on 6 samples is 2 hours as compared with 2 days for the equivalent routine wet-chemical analysis. Other advantages of the spectrographic method lie in the use of small samples and the certainty of detection of uncommon impurities. The spectrographic method has replaced the routine wet-chemical method at the Bureau for the analysis of tin of commercial grades.

Moving a 200-ton Dredge Overland to the New Panama Canal Lock Site.—(*Engineering News-Record*, Vol. 127, No. 21.) Picked up bodily and placed on shore, then skidded 1,800 ft. overland into an artificial pool to begin excavating for the additional locks for the Panama Canal, the 22 in. hydraulic dredge Grand Lake recently completed a long trip begun weeks ahead near Kansas City, Mo. Towed to New Orleans, the dredge was stripped of its machinery and provided with a superstructure for its ocean trip to the Canal Zone. Upon arrival at the Isthmus, the dredge was moored along the canal bank while the superstructure was removed. Then the 100 × 35 ft. hull, weighing 220 tons, was picked up by the floating crane Ajax and placed on a skidway. Sliding on two timber ways, the dredge was slowly moved overland, crossing a highway and three railroad tracks, including the main line of the Panama Railroad. Motive power was supplied by a tractor, using cables and blocks. The dredge was floated into the pool and its machinery re-installed, for the removal of about 2,000,000 cu. yd. of material at the north end of the new Gatun Locks site. As the pool is not yet connected with a waterway, water is being supplied from the canal through a 2,000 ft., 22 in. pipe, fed by two 16 in. pumps, each driven by a 250 hp. motor. To permit dredging to the required 65 ft. depth, the pool surface will gradually be lowered as excavation progresses. The final use of the dredge will be to unwater the pool, in order that hard material that underlies the muck may be excavated and the locks built in the dry.

R. H. O.

THE FRANKLIN INSTITUTE.

STATED MEETING OF THE INSTITUTE, WEDNESDAY, FEBRUARY 18, 1942.

The stated monthly meeting of The Franklin Institute was called to order by Mr. Charles S. Redding, President, at 8:15 o'clock on the evening of Wednesday, February eighteenth.

The audience stood at attention during the playing of the Star Spangled Banner.

The President then read a set of instructions regarding deportment of members of such groups during air raids.

The minutes of the previous meeting were approved as printed in the February issue of the JOURNAL.

The Secretary reported the following additions to the membership during the month of January:

Active	16
Associate	18
Student	56
Total	90

He then stated that, upon recommendation of the Board of Managers, the two Franklin Medalists for the year 1942 were proposed for Honorary Membership:

Paul Dyer Merica, Millwood, New York. and Jerome Clarke Hunsaker, Massachusetts Institute of Technology, Cambridge, Massachusetts.

Upon motion, duly seconded, these two gentlemen were declared so elected.

There being no further business, Mr. Redding introduced the speaker of the evening, Daniel H. Young, C.E., Job Manager, Dry Dock Associates, Navy Yard, Philadelphia, Pa.

Taking as his subject, "Building Dry Docks for Defense," Mr. Young told his audience that during the last eighteen months the Navy Department, Bureau of Yards and Docks, has instituted new methods for the speedy and economical construction of the world's largest ship docking facilities. He described the various operations and demonstrated through the use of color films.

The meeting adjourned at 9:50, with a rising vote of thanks to the lecturer.

HENRY BUTLER ALLEN,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of Stated Meeting held Wednesday, February 11, 1942.)

HALL OF THE COMMITTEE,
PHILADELPHIA, FEBRUARY 11, 1942.

MR. JOHN B. KLUMPP *in the Chair.*

The following reports were presented for final action:

No. 3081: Work of Walter Larkin in the Textile Industry.

This report recommended the award of a Certificate of Merit to Walter Larkin, of Philadelphia, Pennsylvania, "In consideration of his admirable machine designing involving the ingenious application of known mechanical movements to the invention of circular knitting machines of special types."

No. 3093: Propeller Vibration Measuring Device.

This report recommended the award of an Edward Longstreth Medal to Charles Maxwell Kearns, of East Hartford, Connecticut, "In consideration of the successful application of methods for the measurement of strains in aircraft propellers under flight conditions."

No. 3100: Measurement of the Magnetic Moments of Atomic Nuclei and Their Radio Frequency Spectra.

This report recommended the award of an Elliott Cresson Medal to Isidor Isaac Rabi, of New York City, New York, "In recognition of the basic importance of the Rabi magnetic resonance method for investigating the properties of atomic nuclei—an importance already demonstrated by a variety of achievements."

No. 3107: Brown Medal.

This report recommended the award of a Frank P. Brown Medal to Duff Andrew Abrams, of New York City, New York, "In recognition of his discovery of the fundamental bases of design for concrete and reinforced concrete mixtures."

No. 3108: Levy Medal.

This report recommended the award of a Louis E. Levy Medal to John Donovan Strong, of Pasadena, California, for his paper entitled "On a new Method of Measuring the Mean Height of Ozone in the Atmosphere," which appeared in the February issue of the JOURNAL OF THE FRANKLIN INSTITUTE for 1941.

At the January 14, 1942, Stated Meeting, the following report was presented for final action:

No. 3095: Rail Fissure Detector Car.

This report recommended the award of a Howard N. Potts Medal to Harcourt C. Drake, of Hempstead, Long Island, New York, "In consideration of inventions and important work in the development of the rail fissure detector car, affording valuable results in the saving of life and property."

This recommendation was advertised in the February issue of the JOURNAL OF THE FRANKLIN INSTITUTE.

JOHN FRAZER,
Secretary to Committee.

LIBRARY NOTES.

Photostat Service. Photostat prints of any material in the collections can be supplied on request. Orders received in the morning are filled the same day. The average cost for a print 9 × 14 inches is thirty-five cents.

The library and reading room are open on Mondays, Tuesdays, Fridays and Saturdays from nine o'clock A.M. until five o'clock P.M., Wednesdays and Thursdays from two until ten o'clock P.M.

RECENT ADDITIONS.

AERONAUTICS.

Aerosphere's Modern Aircraft. 1941.
MANLY, G. B. Aircraft Powerplant Manual. 1942.

AGRICULTURE AND FORESTRY.

BEAR, FIRMAN E. Soils and Fertilizers. Third Edition. 1942.
TIEMANN, HARRY DONALD. Wood Technology. 1942.

BIBLIOGRAPHY.

Yearbook of Research and Statistical Methodology. Second. 1941.

BIOGRAPHY.

MEADOWCROFT, ENID LA MONTE. Benjamin Franklin. 1941.

CHEMISTRY AND CHEMICAL TECHNOLOGY.

DEARLE, D. A. Plastic Molding. 1941.
ENGELDER, CARL J. A Textbook of Elementary Qualitative Analysis. Third Edition. 1942.
HILDITCH, T. P. The Industrial Chemistry of the Fats and Waxes. Second Edition, Revised and Enlarged. 1941.
MÜLLER, OTTO H. The Polarographic Method of Analysis. 1941.
Organic Syntheses. Collective Volume 1. Second Edition. 1941.
ROBINSON, CLARK SHOVE, AND EDWIN RICHARD GILLILAND. The Elements of Fractional Distillation. Third Edition. 1939.
Society of Chemical Industry. Chemical Engineering Group. Proceedings. Volume 22. 1940.
Thorpe's Dictionary of Applied Chemistry. Fourth Edition. Volume 5. Abridged Index to Volumes 1–5. 1941.

CIVIL ENGINEERING.

Golden Gate Bridge and Highway District. The Golden Gate Bridge. 1937.
HEWES, LAURENCE ILSLEY. American Highway Practice. Volume 1. 1942.

CIVILIAN DEFENCE.

GLOVER, C. W. Civil Defence. Third Edition. 1941.
LANGDON-DAVIES, JOHN, Editor. The Home Guard Training Manual. 1942.

Medical Manual of Chemical Warfare. First American Edition. 1941.
WACHTEL, CURT. Air Raid Defense (Civilian). 1941.
Wartime Building Construction. First American Edition. 1942.

ELECTRICAL ENGINEERING.

Standard Handbook for Electrical Engineers. Seventh Edition. 1941.

HEATING AND VENTILATING.

CLOSE, PAUL DUNHAM. Building Insulation. 1941.
STEINER, KALMAN, AND FRED RAVNSBECK. Oil Burner Service Manual. First Edition. 1942.

INDUSTRIAL MANAGEMENT.

KOEPKE, CHARLES A. Plant Production Control. 1941.

MATHEMATICS.

COOKE, NELSON M. Mathematics for Electricians and Radiomen. First Edition. 1942.
COURANT, RICHARD, AND HERBERT ROBBINS. What is Mathematics? 1941.
DEMORGAN, AUGUSTUS. A Budget of Paradoxes. Second Edition. Two Volumes. 1915.
FORDER, HENRY GEORGE. The Calculus of Extension. 1941.
MERRIMAN, GAYLORD M. To Discover Mathematics. 1942.
NAIDICH, JAMES. Mathematics for the Aviation Trades. 1942.

MILITARY ENGINEERING.

MITCHELL, WILLIAM A. Army Engineering. Fifth Edition. 1938.
SHARPE, PHILIP B. Complete Guide to Handloading. Second Edition with Supplement. 1942.

MINING AND METALLURGY.

American Institute of Mining and Metallurgical Engineers. Transactions: Coal Division, 1938; Institute of Metals Division, 1936 and 1941; Mining Geology, 1941; Petroleum Division, 1937 and 1941.

NAVAL ARCHITECTURE AND NAVIGATION.

DOW, GEORGE FRANCIS. The Sailing Ships of New England. Series Three. 1928.
POLOWE, DAVID. Navigation for Mariners and Aviators. 1942.

PHOTOGRAPHY AND GRAPHIC ARTS.

BAGLEY, JAMES W. Aerophotography and Aerosurveying. First Edition. 1941.
Photograms of the Year 1942.
RAMSAYE, TERRY. A Million and One Nights. Volumes 1–2. 1926.
SCHMIDT, ERICH F. Flights over Ancient Cities of Iran. 1940.
WINANS, LEONARD G. The Book. 1941.

PHYSICS.

KEENAN, JOSEPH H. Thermodynamics. 1941.
LOVE, A. E. H. Theoretical Mechanics. Third Edition. 1921.
Optics and Service Instruments. First American Edition. 1941.
WEBER, ROBERT L. Temperature Measurement and Control. 1941.

RAILROADS.

REED, S. G. A History of the Texas Railroads. 1941.

NOTES FROM THE BIOCHEMICAL RESEARCH FOUNDATION.

Seminar on Chemical Induction of Genetic Changes in Aspergilli.—Dr. Charles C. Thom, of the Department of Agriculture, gave a seminar before the staff of the Biochemical Research Foundation on January 13, 1942, on "Chemical Induction of Genetic Changes in Aspergilli."

Dr. Thom described some of the many variants of *Aspergillus niger* that have been found in nature. These variants differ from the original description of *A. niger* in many particulars. Morphological differences, such as differences in the size of fruiting heads, and spores, and in stalk length, are common and apparently are as fixed as are the differences in biochemical behavior. An example of the variation in this latter characteristic was shown by the work of Thom and Currie on the production of oxalic acid by various strains. These workers demonstrated that some strains would produce ten times as much oxalic acid as would others.

The sporadic occurrence of these many variants in nature raises the question whether they arise directly from the effect of environment on a typical strain or whether they are really distinct species which show differences warranting separation. If variants similar to those found in nature could be produced in the laboratory by simple means, it would indicate that such variants should not be considered as separate species, and further, that the concept of the species should be considerably broadened.

By growing *A. niger* on a synthetic medium containing sodium nitrite, many variants were produced. Many of these variants duplicated forms found in nature, which had been isolated from practically all parts of the earth. Especially interesting was the correspondence between these chemically produced variants and those described by Mosseray, which included 63 strains selected over many years from miscellaneous material from the Belgian colonies, especially in Africa.

The results of this nitrite stimulation were quite consistent and were readily duplicated. The same types of variants were produced in successive experiments, each beginning with the unchanged stock culture, which had been kept for more than twenty years essentially unchanged. The colors of the variants ranged from the original black to pure white and canary yellow. Practically all the morphological differences found in variants obtained from nature were duplicated in these nitrite variants, and these differences persisted on subculture.

Many chemical agents were used in this study on *A. niger*. Thirty-seven dyes and biological stains were tested, but the results could not be duplicated at will. Colchicine, which has been so widely used to induce polyploidy in plants and which interferes with cell division in animals, was found to have no effect. Eighty-five different phenanthrene derivatives were tested, but without results. The lack of effect of these compounds on *A. niger* was of a great deal of interest, for some of these compounds are the most powerful carcinogenic agents known. The ease with which they produce neoplastic changes in human and animal tissue, contrasted with the lack of effect on *A. niger*, indicates that the fundamental mechanism by which changes are induced in various types of living organisms may vary widely.

Certain other chemical agents were able to produce changes, but none of them was as efficient in this regard as sodium nitrite. Potassium iodide, Chloramine T, ninhydrin, formin, and potassium bichromate served to induce variation. It is noteworthy that the types of variant obtained with these chemicals were about the same as those obtained with sodium nitrite, and were also quite similar to those found in nature. Evidently, then, *A. niger* tends to vary in certain rather definite directions, whatever the cause inciting the variation.

The exact mechanism by which these chemical agents induce the production of variants is not known. However, it appears quite likely that it is through their action on the amino nitrogen of the protein in the living protoplasm. No chemical compounds which would not unite with amino groupings were found to have any effect.

This induction of genetic changes by simple chemical compounds has demonstrated that almost all of the variants of *A. niger* isolated from nature can be produced at will in the laboratory from one known strain; that variation tends to be along certain well-defined paths; and that various chemical compounds are capable of inducing practically the same variations. It would be interesting to see whether this technique could be extended to the flowering plants to ascertain whether variation in this form of life can also be controlled by such simple means.

BOOK REVIEWS.

CHEMISTRY FOR PHOTOGRAPHERS, by Allen R. Greenleaf. 177 pages, illustrations, 14 × 21 cms. Boston, American Photographic Publishing Co., 1941. Price $2.00.

In photography as in other lines of work, the curious worker eventually produces the best results. When curiosity has begun to be satisfied the work begins to take on new meaning. Not only are the results more appealing to others, but, of even greater importance, the worker has inwardly produced more than others can appreciate. Chemistry plays a necessary and fundamental part in photography. The curious minded photographer unless he is guided along certain paths, will have difficulty in learning much about the chemistry of photography and may easily be discouraged. Chemistry is a great subject. The portion of it of interest to the photographer must be selected with care. It must be shaped properly, abstracted, and presented in a manner understandable to the photographer, in order that sufficient scope be had as well as sufficient detail to provide proper background. That is the purpose of this book.

It starts out by giving definitions of chemical terms in such a manner that the use of symbols and equations can be kept to a minimum in the rest of the book. The reader need have no fear that this kind of material will get the best of him. The greater part of the book is devoted to the various chemical processes of photography. There are discussed emulsions, reducing agents and developers, desensitizers, intensification and reduction, toning, various reactions, etc. Dark room equipment and practices, a description of weights and measures, a formulary and a subject index complete the book. It provides a valuable addition of knowledge for the photographer, professional and amateur, that will undoubtedly make his work more pleasurable and better. It is a source of information and a reference.

R. H. OPPERMANN.

THE IDENTIFICATION OF MOLECULAR SPECTRA, by R. W. B. Pearse and A. G. Gaydon. 221 pages, 20 × 28 cms. New York, John Wiley & Sons, Inc., 1941. Price $8.00.

Pure spectroscopists as well as those who use spectroscopy as a tool for research such as in astrophysics, chemistry, and chemical technology will find here an invaluable book of information about known band spectra which may assist in their identification. The difficulties that arise in identification are recognized by the authors and the data contained in the book are arranged accordingly. The first part of the book consists of a table of persistent band heads, the object of which is to provide a clue to the nature of the unknown band system as quickly as possible so that it may be compared directly with the appropriate detailed list. For this purpose it contains, for all suitable band systems of frequent occurrence, a selection of the outstanding heads, which are most conspicuous under various conditions of excitation, arranged in order of wave-length in air in International Angstroms from 10,000 down to 2,000 to the

nearest 0. IA. Bands of particular occurrence as impurities are marked, as are data for the head of a band degraded to longer (red), shorter (violet) wave-lengths or is the maximum of a headless band. The table also includes intensities, sources, appearance, and occurrence.

The greater part of the book is devoted to individual band systems. In this section detailed lists of bands are given for each system separately and are arranged in alphabetical order of the chemical symbols of the molecules concerned. For each molecule a few general introductory remarks are made at the beginning if the spectrum is particularly important or complex, and then the various band systems are dealt with separately. The treatment for the systems varies somewhat according to the particular case, but the spectrum is usually dealt with under one or more of the headings of occurrence, appearance or transition. References are given to those papers which are most useful for the purpose of identification.

Another section of the book contains a few brief notes on various minor points which arise in the identification of molecular spectra usually not dealt with in general textbooks. An appendix contains a table of the most persistent atomic lines for each element which is of assistance in checking the presence of atoms. And finally, a number of plates are included showing many of the more frequently encountered band systems.

R. H. OPPERMANN.

FATIGUE OF WORKERS, by the Committee on Work in Industry of the National Research Council. 165 pages, 16 × 24 cms. New York, Reinhold Publishing Corporation, 1941. Price $2.50.

On November 13, 1937 a "Conference on a Scientific Study of Industrial Labor Conditions" was held in Washington under the auspices of the National Research Council. Following this conference and in accordance with a vote of the administrative committee of the National Research Council, a "Committee on Work in Industry" was appointed by the President of the National Academy of Sciences. According to the statement made at the time of its appointment, the Committee was to "consider the scientific study of the physiological and psychological discomfort and distress of workers in industry." This book is a report of the work of the Committee.

The various investigations studied include the effects of heat and high altitude, some industrial causes of illness, the revelations of the researches carried on in the Western Electric Co. plant with regard to light intensity and worker efficiency leading to the important discovery of psychological reactions and effect of social environment, the interview method as a means of investigation in industry, self expression and labor unions, extra-time allowances, and a study of organization. The method used in presenting the findings of the Committee and the discussion of the results is such that understanding is easily had. In the back of the book there is a summary consisting of a series of brief statements on a few of the important conclusions reached in the course of the investigations which have been studied.

The work is the result of a painstaking and weighted inquiry of those factors which have direct bearing on industrial relations and human efficiency in industry. The conclusions are simply and fearlessly laid down so that they may be readily applied.

R. H. OPPERMANN.

PHOTOELASTICITY, Volume I, by Max M. Frocht. 401 pages, illustrations, plates, 16 × 24 cms. New York, John Wiley & Sons, Inc. Price $6.00.

Never has stress analysis played a more important part in our industrial picture than it does today. The proper functioning of much of the machinery vital to the nation's welfare is dependent upon precision in determining stresses, especially local in nature. The several older methods for exact stress analysis, because of their unwieldyness when irregular loads appear, have been replaced by experimental methods and it is here that photoelasticity becomes a powerful technical instrument, which, once understood, can be used with speed and accuracy.

This Volume I on the subject is a treatise on fundamental principles and methods, i.e. methods for plane stress analysis based on the stress pattern and the isoclinics. Methods which depend upon additional experiments, such as the measurement of lateral deformation, and which do not necessitate transparent models will, according to the author, appear in a later volume.

The treatment here is aimed to be within the scope of the average beginner. Prerequisites are stated as differential and integral calculus and a first course in strength of materials. Written in the form of a text, the book consists of eleven chapters covering some 400 pages. Mathematical developments are presented in abundant detail, as are most of the necessary elements of elasticity. First there is given a review of stresses and strains at a point, and stress-strain relations. This is followed by an exposition of the differential equations of equilibrium in different coördinates. Preliminary optics and polarized light are studied which involves the transverse ether wave theory of light, the kinematics of simple harmonic motions necessary for its understanding and its relation to polarized light. There is a discussion of permanent double refraction and an explanation of the optical phenomena of polariscopes. The stress-optic law in two dimensions is stated and proved, and the theory and interpretation of the photoelastic stress pattern are developed. In a section dealing with isoclinics and stress trajectories, attention is directed to the fundamental theorem on stress trajectories, which has a number of important applications in photoelasticity. This is new.

A special method for the determination of principal stresses across sections of symmetry known as the Slope Equilibrium Method is presented, and a treatment is given on the shear difference method, which rests on the differential equations of equilibrium in Cartesian coördinates. The latter part of the book deals with Filon's graphical integration for the direct determination of principal stresses across stress trajectories, photoelastic materials, and a description of the elements of equipment and the art of making a reliable and attractive stress pattern with emphasis on boundary visibility.

The straightforward method of presentation, the use of the many illustrations and diagrams, and the logical progression make this book a good text for the student and a valuable reference work to the designer.

R. H. OPPERMANN.

PHOTOGRAPHIC EMULSION TECHNIQUE, by T. Thorne Baker. 263 pages, 14 × 20 cms. Boston, American Photographic Publishing Co., 1941. Price $4.00.

Photographic emulsions are not all made by the manufacturer. Even aside from research work, there are many reasons why emulsions should be and are made by the individual. Technical students of course are interested. Industrial

Chemists and photographers have cause to prepare emulsions of various types and speed. This book is a text and guide to practical emulsion making.

Starting out with a discussion on the nature of photographic emulsions, the author, in language easily understood by the layman, proceeds to explain the technique for making photographic emulsions. The materials necessary are described, their handling, storage, analyzing and testing as well as the laboratory equipment and layout. The first consideration of emulsion making is that of negative emulsions, including the fast emulsion. This leads to the making of the comparatively slow emulsion, of 25 to 150 H and D. Color sensitive emulsions form a very interesting part of the book as does the coating of emulsions on glass. Other subjects covered include bromide and chloride papers; negative and positive films; printing out emulsions; testing emulsioned products; various metallic processes; and extreme-speed emulsions.

The book has many diagrams and illustrations. At the end there is a useful subject index. The book makes available to photographers and others information that heretofore was available only to those who cared to study in a foreign field and who were educationally prepared to do so. Many readers of this book will find that it provides a new realm of activity for them to explore. All readers will benefit by way of better work results which will come from a more complete knowledge of the photographic process.

R. H. OPPERMANN.

THE MICROSCOPE, by Simon Henry Gage. 617 pages, illustrations, 16 × 24 cms. New York, Comstock Publishing Co., Inc., 1941. Price $4.00.

A book which goes through its seventeenth edition is so unusual that it draws immediate attention. It must have proved extremely useful; it must have been popular; its accomplishments must have been great; it must have kept up with the progress of the subject. The book at hand is in its seventeenth edition, and it has all of these attributes and more. For many years it has been the guide to those unfamiliar with the microscope and methods of work with it, to gain an intelligent understanding of the instrument, its limitations, and its possibilities for aiding to arrive at truth. Essentially explanatory, the book retains its original character. Revisions have been made so as to make the subject more easily understood as well as to keep up with new apparatus and methods.

There are fifteen chapters to the book. Starting with descriptive matter of microscopes and their parts the treatment leads through light and dark field microscopy, the polarizing microscope, the micro-spectroscope and the ultra-violet microscope. These chapters also give operation details and theories. Next, information of a more general nature such as the interpretation of appearances, magnification and micrometry, and drawing with the microscope and with projection apparatus is presented. The latter chapters, after attention is given to photography and equipment for mounting, are devoted more to the use of the microscope. They include fixing and preservation of tissues, serial sectioning of organs, small animals and embryos, micro-incinerations and the optical appliances for their examination. The last chapter of the text gives a brief history of lenses and microscopes. There are lists of references for collateral reading in connection with many of the chapters, a general bibliography and a subject index which adds much value to the book. The many drawings and illustrations supplementing a

clearly written text all contribute to a valuable tool for all those interested or who will be interested in the microscope and its uses.

R. H. OPPERMANN.

EDUCATION ON AN INTERNATIONAL SCALE, by George W. Gray. 14 pages, illustrations. 15 × 22 cms. Harcourt, Brace & Co., 1941. Price $2.00.

The International Education Board consisted of a body of trustees and a staff of officers. It was founded in 1923 by John D. Rockefeller, Jr. for "the promotion and advancement of education throughout the world." Established as a post-war measure, its purpose was to mitigate as far as it could be done the impoverishment of educational and other intellectual resources consequent upon the World War. During the period of its greatest activity, 1923–28, it rendered assistance to hundreds of key men and scores of institutions in thirty-nine countries, fostered and underwrote human interests over a wide territory, ranging from such erudite studies as mathematical theory and astrophysics to such practicalities as animal husbandry and a world census of agriculture, and here and there replenished some candles of learning that cannot be destroyed. This is the story told in this book.

The guiding genius to these accomplishments through Mr. Rockefeller's support was Dr. Wickliffe Rose. It was through him that the award of so many dollars resulted in an ever-widening circle of enlightenment. To be able to evaluate progress in and ability for the furtherance of knowledge in agriculture and the natural science is a task few would or could undertake. The work of Dr. Rose is related here, his method and his results. The story is illuminating not only in this respect but in the almost unbelievable extent of helpfulness given to work the results of which are only too often taken for granted.

R. H. OPPERMANN.

ACOUSTICS OF BUILDINGS, by F. R. Watson. Third edition, 171 pages, illustrations, 16 × 24 cms. New York, John Wiley & Sons, Inc., 1941. Price $3.00.

The advent of talking motion pictures, of public address systems and of measurements of inefficiencies in human activities due to noise interruptions have encouraged inquiry into noise and its control. Almost unbelievable betterment of conditions has resulted. The subject is similar to others in that the pace of development is sharply accelerated in recent years. In the past ten years, advances in this subject have been rapid and surprising. Evidences of this are not wanting. The theory of reverberation in rooms has been advanced through a study of the so-called "normal modes" of vibration, and new formulas have been evolved that apply particularly to small rooms. Experimental disagreements in the values of absorbing coefficients are being reconciled by measurements of "acoustic impedance." These and other advances are included in the book at hand which is a rewriting of the second edition of 1930.

One feature of the book is its thoroughness. The subject has been divided into three parts: general phenomena of sound that apply to buildings, acoustics of rooms, and sound insulation. And the subheadings of each of these parts reflect an ordered presentation and logical progression. Closer examination reveals that within the scope of the work, close consideration is given to details, the importance of which becomes evident when reference is made to the problems

of a practical nature in the back of the book. Another feature of the book is clarity. Only simple language is used. The use of technical terms is restricted to sentences of simple construction, the meaning of which is quickly grasped with a minimum possibility of misunderstanding, yet the treatment is not jerky or abrupt.

The theory as it is presented is readily applicable to practice. It is authoritative and represents the latest aspects of the subject. As a text and reference work of unusual qualities, the book can be recommended.

R. H. OPPERMANN.

GASEOUS CONDUCTORS, THEORY AND ENGINEERING APPLICATIONS, by James Dillon Cobine. 606 pages, 16 × 24 cms. New York and London, McGraw-Hill Book Company, Inc., 1941. Price $5.50.

There was a time not long past when interest in gaseous conductors was primarily academic, commercial applications being few in kind. These applications have now been developed to be more efficient and new uses are already here. To meet the engineering needs resulting from the new and more efficient uses of gaseous electrical conduction, this book is presented. It is a text which early recognizes that the engineering viewpoint of this subject as distinct from that of the physicist, must be developed. The author states in the preface, "It is seldom that engineering students receive such training in the usual physics courses as to justify complete omission of this part (fundamentals) of the book," from which it can be taken, and the subsequent treatment confirms, that physical fundamentals are prepared and presented especially for engineers. On this, of course, is built the rest of the engineering treatment.

The work opens with an introduction to the kinetic theory of gases which leads to treatments on atomic structure and radiation, ionization and deionization, emission of electrons and ions by solids, space charge and plasma breakdown of gases, and glow discharges. Considerable space is devoted to the electric arc and differentiation is made between the low pressure arc and the high pressure arc. Here, there is included analysis of the former by Langmuir and Tonks, and of the latter by Suits. Likewise, attention is given to circuit theory. The study of the illuminating properties of electrical discharges as here given is both important and interesting for it provides opportunity for observing many of the phenomena previously discussed. Consideration is finally given to the cathode ray oscillograph.

One of the prerequisites for the use of this text is a knowledge of mathematics up to and including the calculus. It is used freely throughout the text. A considerable number of experiments are outlined which assist greatly in developing the subject. Liberal use is made of diagrams, curves and drawings to facilitate understanding. There is appended numerous tabular data, and a subject index useful for reference purpose.

The book deserves attention particularly from instructors in colleges and universities. It also is of value to engineers desiring to improve their knowledge of the subject.

R. H. OPPERMANN.

ANHYDROUS ALUMINUM CHLORIDE IN ORGANIC CHEMISTRY, by Charles Allen Thomas. 972 pages, 16 × 24 cms. New York, Reinhold Publishing Corporation, 1941. Price $15.00.

Reactions involving the use of anhydrous aluminum chloride are applied in many fields of organic chemistry. The brilliant work by Freidel and Crafts has been used as a basis and during past years the amount of material on this subject has grown enormously. Because of the importance of the subject the diversity of its applications, the wide scatteration of the literature pertaining to it, and its potential possibilities, the book "Anhydrous Aluminum Chloride" is valuable.

This book, like other American Chemical Society Monographs, is the result of an exhaustive search for literature on the subject, its classification and arrangement in proper order, and the application of expert knowledge in presentation of it in a style readily usable by those interested. The subject is examined from every angle here, and there is recorded developments from the time of the early work to the present. First, there is discussed the physical properties of anhydrous aluminum chloride, then the mechanism of reactions catalyzed by it. The coverage of Freidel and Crafts synthesis reactions consumes considerable space and following this is discussion on a group of addition and miscellaneous reactions. This comprises mainly the study of aluminum chloride as an active agent in promoting the addition of aromatic compounds to olefinic double bonds, and the synthesis of keto-acids from dicarboxylic anhydrides. Subsequent topics treated are aldehyde synthesis, aromatic halogenation, dehydrating condensations, and the use of the anhydrides of aliphatic monocarboxylic acids to prepare alkyl aryl ketones to give products which are purer than those obtained from the corresponding acyl halides. The general character and influence of aluminum chloride on aromatic compounds, next taken up, includes a table comprising a list of observations made concerning products secured. The production of polynuclear hydrocarbons by self-condensation of the aromatic component during Freidel-Crafts alkylation is included in the table.

The latter part of the book is devoted to the rôle of anhydrous aluminum chloride in aliphatic chemistry, in the petroleum industry and as a powerful polymerizing agent, as well as its preparation, manufacture and purification. Concluding is a section of notes on application of anhydrous aluminum chloride such as storage and transportation, influence of moisture and purification.

There are many diagrams, curves and tables throughout the work. It is well presented, containing much evidence of masterful exposition. All of the many references are listed including U. S. and foreign patents. Contributing to the value of the book as a reference work are the author and subject indexes in the back. The book provides a suitable summation of the work of a great many investigators. As such it has value to those interested in the many phases of the subject as a text and reference.

R. H. OPPERMANN.

INDUSTRIAL AND ENGINEERING CHEMICAL TECHNOLOGY, 102 pages, 22 × 28 cms. and CHEMICAL PROBLEMS AND THEIR SOLUTIONS, 107 pages, 22 × 28 cms., by Francis Wm. Brown, Ph.D. Philadelphia, Industrial Consultants, 1941. Price $1.50 each.

These two books are in the form for brief courses for practical training. The subjects are broken down into small divisions and each is given a short statement as to its character or use, or both.

The first book—Industrial and Engineering Chemical Technology—covers metals, alloys, corrosion problems, mineral acids, alkalies, carbon, sulphur, gases, liquids, solutions, etc., etc.

The second book—Chemical Problems and Their Solutions—after treating on elementary mathematics, gives both chemical and physical type of problems. These problems are arranged after the short statement concerning the topic, as illustrative of the statement. The problems are worked out and the answers arrived at.

R. H. OPPERMANN.

PUBLICATIONS RECEIVED.

What is Truth?, by Glen Hilding Draper. A Philosophy Challenging the Authority of Mathematics. 122 pages, 15 × 21 cms. Washington, D. C., Ransdell Incorporated, 1941.

Chemical Problems and Their Solutions, by Dr. Francis Wm. Brown. 107 pages, 9 × 11 cms. Philadelphia, Industrial Consultants, 1941. Price $1.50.

Engineering Surveys, Elementary and Applied, by Harry Rubey, George Edward Lommel, and Marion Wesley Todd. 664 pages, illustrations, tables and index—170 pages. 13 × 20 cms. New York, The Macmillan Co., 1942. Price $4.50.

College Physics, by A. Wilmer Duff and Morton Masius. 588 pages, illustrations, 15 × 23 cms. New York, London, Toronto, Longmans, Green and Co., 1941. Price $3.80.

Modern Pulp and Paper Making, a Practical Treatise, second edition, by G. S. Witham, Sr. 705 pages, illustrations and plates. 16 × 24 cms. New York, Reinhold Publishing Corp., 1942. Price $6.75.

CURRENT TOPICS.

New Type Boiler for New England.—(Stone and Webster Bulletin, Vol. 9, No. 4.) The first "controlled forced circulation" steam boiler to be installed in this country is being erected in the Somerset Station of the Montaup Electric Company near Fall River, Massachusetts. This boiler has a continuous steam generating capacity of 650,000 pounds per hour at a pressure of 1825 psi and 960° F. It will supply steam for a 25,000 kw. "topping" turbine the exhaust from which after reheating will be sufficient to generate 47,800 kw. in two previously installed 375 psi condensing turbines. Several years ago Combustion Engineering Company, Inc. acquired the American rights for the manufacture of this type of boiler. While over 700 such units are in operation in Europe, this is the first time that the principle of controlled forced circulation has been used in this country. Great care has been taken to insure that the unit will meet the standards of reliability and efficiency demanded by the American utility industry. When Somerset Station was designed and constructed, space was provided for an additional boiler of 200,000 pounds per hour output at 375 psi. The new boiler will occupy this vacant space but will have more than three times the capacity of the boiler contemplated originally. To have installed the conventional type of natural circulation boiler would have required extensive and expensive remodeling of the building and the forced circulation design was adopted to keep within the confines of the present building and to insure proper circulation. The boiler resembles in general arrangement those having natural circulation except that circulation is effected by means of centrifugal pumps which force the water through the steam generating tubes. These tubes are $1\frac{1}{4}$ inches outside diameter and the ratio of water circulated to steam generated is about 3.85 to 1 as compared with the ratio of 10 to 1 for a natural circulation boiler. Three circulating pumps will be installed, one of which is to be held in reserve, as two will provide full circulation for the boiler at maximum output. Each pump will require 175 hp. and will have a capacity for circulating about 1,400,000 pounds of water per hour.

R. H. O.

Army Uses New Throwing Device to Speed Laying of Field Wires.—United States Army Signal Corps engineers have developed

a wire thrower designed to speed up the laying of field wire used in maintaining communications under combat conditions, the War Department recently announced. The new equipment will be used by Signal Corps units operating with Army Corps and Divisions, establishing communications between Corps or Division Headquarters and units under their command. With the new thrower, wire can be thrown from a moving vehicle to distances up to 125 feet away and at vehicle speeds up to 35 miles an hour. An operator has control of the distance and slack by varying the speed of the thrower. By using the new wire thrower, wire can be laid at greater speeds and placed further off the road, thus requiring a minimum of servicing. Field wire has been laid and recovered in the past by Signal Corps troops with a unit mounted on a vehicle and possessing a self-contained power drive for reeling out and recovering wire from directly behind the vehicle. Faster moving mechanized troops and greater distances between command posts in the expanding army have made it necessary to provide a faster means of laying field wire for communication circuits off the road in order to require a minimum of servicing.

R. H. O.

The Incomplete Angler.—(Industrial Bulletin of Arthur D. Little, Inc. No. 175.) Over twenty-three million Americans "go fishing." Their ideas of how, when and where to fish vary, and contrary to popular belief, the small boy with his alder pole is not as successful as his elder with the latest equipment. The desire for more and better tackle, inherent in all fishermen, young and old, is reflected in constant demand for better quality rods, reels, lines, leaders and bait. Synthetic materials have made their way into the sacred trinity of rod, reel and line, and also baits, leaders and packaging. One of the newest offerings is a split bamboo rod impregnated with Bakelite, apparently with no increase in final weight and with a waterproof "no varnish" finish which cuts down upkeep. Transparent crystal plastic line coilers and fly boxes and colored plastics for reels, reel seats and handles of quality rods are among the many plastic products. Nylon lines meet increasing demand as defense makes silk less available for casting and fly lines. Synthetic leaders formerly made from silk covered with starch compositions are now made from nylon or Vec and other synthetic substances. Various types of lines are now treated chemically before being braided and are then waterproofed with oil, enamel or tar to doubly insure water-shedding ability. Special new dressings for fly fishing are said to keep lines afloat for several hours of use and

lessen the friction drag of enamels through rod guides. New coats of many colors, appealing to the fisherman's eye and camouflaging the lines in the water, range from black, greens, blues and flecked tones to semi-transparent. A new method of twisting linen lines is claimed to keep them "right twisting," preventing unstranding and water-logging through twisting to the left when wet. New "deep-water" trolling lines use bronze, stainless steel and other non-rusting metals. With great strides in tackle improvement, easy transportation to distant waters and increasing numbers of fishermen, concern might be felt for the future of fishing. A more sportsmanlike attitude, however, a trend toward smaller diameter lines and use of lighter tackle, together with greater interest in fly fishing, are resulting in smaller takes.

R. H. O.

Invention for Defense.—L. B. LENT of National Inventors' Council, Washington, D. C., presented a paper at the annual meeting of the A. S. M. E. which appears in *Mechanical Engineering*, Vol. 64, No. 1. With regard to how engineers can help in defense Mr. Lent stated that in the first place it must be kept in mind that inventive ideas which may develop in connection with one's own job may have some application in problems of defense. Examples of this are innumerable. A method of rolling steel tubes, now in wide use, has recently been found applicable in the rolling of liners for big guns. Next, give assistance to subordinates with inventive ideas. Help them to organize their ideas and prepare their material for orderly consideration by others. Don't forget that it was a woman who planted in the inventive mind of a young tutor named Eli Whitney the idea that a machine was needed to remove cottonseed from the fiber. You never can tell where some worth-while idea may come from. Also, discuss inventive ideas of your subordinates with them. A large percentage of inventions coming to us are found useless because the inventor is not familiar with the prior art nor is he well grounded in the fundamental physics or mechanics upon which his invention is based. For example, many inventors think of sound waves or light waves as a prime medium for energizing a projectile for chasing airplanes—"bloodhound projectiles" we call them. But they forget that airplanes now race through the air at about half the speed of sound. By the time the sound from airplane engines reaches the sound detector, the airplane may be two or more miles away from where it was when the sound left it. Neither visible light waves nor infrared rays penetrate fog or dense haze; so that source of detection is not so good. Radio waves seem

to be most promising as an element in remote-control devices. Finally, don't forget that some ideas, which may not be useful in connection with a particular device, may find a most useful application in some other field. Examples of this are numerous.

R. H. O.

Dolomite and Sea Water Used for Making Magnesia Refractory.—(*Mining and Metallurgy*, Vol. 23, No. 421.) Construction work for the new plant of the Northwest Magnesite Co., Pittsburgh, is actively under way at Cape May Point, N. J. The Company, jointly owned by the Harbison-Walker Refractories Co. and General Refractories Co., has acquired the rights in the United States to the Chesny process of producing synthetic magnesite for refractory purposes. To operate the process, the Company has acquired a large tract at Cape May Point, together with extensive deposits of dolomite in eastern Pennsylvania, located conveniently for shipment either by rail or by rail and water. The capacity of the first unit will be approximately 40,000 tons per year. Additional units may be added. The process was developed in England by H. H. Chesny, a resident of Los Angeles, Calif., working in coöperation with British producers of refractories. The process consists essentially in replacing the lime content of calcined dolomite by magnesia through reaction with sea water. Its commercial success is the result mainly of specialized knowledge of the involved crystallography of magnesium hydrate. This compound in its usual form is a gelatinous substance exceedingly difficult to filter. Only by the application of a highly specialized technique can it be produced in a crystalline, readily filterable state and easily separable from the sea water and from the various salts dissolved in it. A further factor in the success of the process has been the design and development of the highly specialized equipment required to meet the conditions of its various steps. During the late fall of 1939, Northwest Magnesite Co. materially increased the capacity of its present plant at Chewelah, Wash. Still further facilities, including a system of concentration by flotation, have been under way for several months, and these additions have nearly doubled the capacity prior to 1939. Any possible demands for magnesite in the basic steel industry should now be adequately taken care of as they may occur.

R. H. O.

Tests Show Effectiveness of Flame Cleaning Structural Steel.—E. A. TICE. (*Steel*, Vol. 110, No. 6.) During the last few years, intense interest has been aroused among structural steel fabricators in the development of methods of preparing steel surfaces for primer

painting. They have been anxious to find a method which would extend the life of priming paints on structures, and which would be less hazardous, less costly and generally more satisfactory than sand blasting. Many attempts have been made to prepare the surface for painting, involving chemical treatments and mechanical cleaning methods. One method has attracted keen interest—flame cleaning with the oxyacetylene torch. At Bethlehem Steel Co., this method was inaugurated in 1938. With some experience in mind, as reported by the British Iron and Steel Institute in 1938, and being acquainted with the oxyacetylene torch method for scarfing billets in mills, Bethlehem engineers proposed the idea of using an oxy-acetylene torch to prepare structural steel surfaces for painting. The investigators believed the chief benefit derived from flame cleaning would be the removal of moisture occurring both in the free and the combined states on the steel surface. Other benefits would be the removal of some scale and rust. Two investigations were initiated—the first in 1939 and the second in the spring of 1940. The results obtained (tests are still being carried on) indicate that for steel which has not been allowed to rust, but which has only a normal covering of mill scale, good paint life is obtained both after wire brushing and after flame cleaning. For steel which has been exposed to the weather for a considerable time, the situation is different. Here flame cleaning appears to be distinctly superior to wire brushing as a method of preparing steel surface for painting. It has produced up to 100 per cent. longer life.

R. H. O.

Clearing the Grand Coulee Reservoir.—(*Power Plant Engineering*, Vol. 46, No. 2.) The clearing of 54,000 acres of rugged and timbered terrain for Grand Coulee reservoir, one of the largest land clearing operations ever undertaken by the Work Projects Administration, is now virtually complete. This project employed approximately 3,000 men at its peak and utilized a total of 10,000,000 man hours of labor in a clearing task which, while less spectacular than the construction of the dam proper, was absolutely essential to Grand Coulee's operation. To assure a reservoir free from floating debris that might injure the dam and its machinery or interfere with navigation and other developments, it was necessary to clear the canyons and valleys of four rivers, the Columbia and its tributaries—the Sanpoil, the Kettle, the Spokane—and rid them of thousands of trees and tons of undergrowth and debris. Thousands of buildings also had to be removed or demolished and more than 3,000 people evacuated from the area.

R. H. O.

Spot Welding Aluminum at Lockheed.—HARRY L. CHILES, Spot Welding Engineer of the Lockheed Aircraft Corp., describes the modern welder and its work in *Iron Age*, Vol. 149, No. 5. The machine is an adaptation of a new type of welder introduced in 1939. This machine was manufactured in Paris, France and differed in many respects from conventional single phase welders. The most important features are: (1) The "stored energy" principle of operation; (2) The use of direct current for welding; (3) The variable pressure cycle. This stored energy type of spot welder has probably done more to permit the widespread use of spot welding in the aircraft industry than any other one factor. The welders operate from a three phase supply, through a three phase mercury-arc type tube rectifier. This energy is stored as magnetic energy in the welding transformer reactor. When the energy has reached a preset valve a contactor opens the primary d.c. circuit, introducing a very high transient current discharge through the secondary or welding circuit. The 40 kw. spot welder, which welds aluminum alloys up to and including two sheets of 0.081 in. thickness, draws a maximum current of 75 amp. from a 440 volt through phase power supply. Single phase spot welders in the Lockheed shop having about the same secondary area and capable of welding the same material draw a maximum of about 2,000 amp. from a similar supply. This one advantage of the new welder enables a smaller size electrical service and in many cases makes possible the use of such welding machines where otherwise the size of the power system would prohibit its use. The introduction of the reactor stored energy machines also stimulated development of stored energy welders that operate on the condenser discharge principle. The pressure mechanism of this welder is so designed that either a constant or variable pressure cycle may be used. During recent months spot weld production at Lockheed has increased very rapidly and there has been a general increase in efficiency of the spot welding department.

R. H. O.

New Petroleum Research Laboratory Formally Opened.—(*Chemical and Engineering News* of the American Chemical Society, Vol. 20, No. 2.) The Standard Oil Co. of Ohio's new research laboratory adjacent to Western Reserve University in Cleveland was formally opened recently with a public reception and immediately went into action on vital research problems linked directly to America's fight for victory. Five separate laboratories, a large engine testing room, and cold room provided in the building com-

bine practically every known facility for development of higher octane gasolines, Diesel oils, and other fuels, new lubricating oils and greases, better asphalt products, and new by-products of the refining process. The research staff will be concerned with development of improved manufacturing processes as well as improvement of petroleum products and their more efficient use. For this reason one lofty room, two stories high, with a large hatch in the roof has been provided to accommodate any experimental refinery set-up they might have occasion to erect. A completely equipped machine shop has been included in the layout and will enable the laboratory to build any required experimental equipment. An elaborate ventilating system, specially designed to meet requirements for control of conditions in the laboratories and engine testing rooms, delivers filtered air throughout the building, ensuring a complete change of air every six minutes. While the entire structure, including the offices, has only 14,000 square feet of floor space, it has more than a mile of steel pipe in the various systems which distribute gas, water, steam, compressed air, and vacuum to the work tables, test stands, and equipment in the several laboratories. More than 2,000 different chemicals, including many rare substances not available anywhere else in the locality, will be carried in stock in the large chemical storage room on the second floor. In keeping with the cooperative principles which lead to the location of the laboratory at the university campus the rarer chemicals will be available for use by other departments of the university on a replacement basis.

R. H. O.

A Work-Week Plan for Chemical Industry.—R. R. LYMAN AND D. F. OTHMER. (*Chemical and Metallurgical Engineering*, Vol. 49, No. 1.) A working schedule for seven-day, full-time operation of a factory which provides exactly the same conditions for all workers and gives each man five full days of 24 hours off every week has been in successful practice for over four years at the Gray Chemical Co., a well integrated, modern wood distillation plant manufacturing charcoal, refined acetic acid, various grades of methanol, activated carbon, and rough and finished lumber. The novel plan is really based on the substitution of new time units for the usual ones: instead of a 24 hour day a 32-hour cycle (four 8 hour-shifts); instead of a seven day week, a four day rotation; and instead of a calendar month, four weeks (28 days of seven rotations), which period acts as a common denominator of days, shifts, cycles and weeks. In operations requiring 168 hours of work per week, scheduling is usually done with four operators, one of whom must always

be at the post. On equal division of time, each worker must spend one quarter or 42 hours per week. The problem is to allot time to treat fairly the four men and have the minimum disadvantages in changing schedules. Habits, outside activities, sleeping considerations, wage-hour laws and many other factors must be considered. The Gray plan of progressive-rotation follows the simplest possible pattern. A man works eight hours, is off 24 hours and repeats indefinitely without change. Thus, out of 32 hours, A is on eight, off 24 and tends the post one quarter of the time. B takes over at the end of A's shift and then is also always on eight hours and off 24. C follows B identically and D always follows C to complete the cycle. There are never any "shift changes"; every man's lot is always identical; and they all "progress" and "rotate" consecutively. Since there are three shifts of eight hours per day and four of these in the four man cycle, at the end of four days the rotation is complete and every man starts his shifts at the same hour as he did the first day; and each man has worked each of the three shifts. Unfortunately, however, the days of the calendar week are seven; and four day rotations and seven-day weeks will not end together oftener than every 28 days.

R. H. O.

Troop Carrying Gliders.—(*Manufacturers Record*, Vol. 111, No. 1.) The Navy Department recently announced the award of contracts for the manufacture of a number of experimental gliders. Included is a contract for 12 place troop carrying gliders to Allied Aviation Corporation of Baltimore. The general lines of this glider whose overall dimensions approximate those of the Douglas DC-3, were originally laid out by the engineering offices of the Naval Aircraft Factory in Philadelphia, under the direction of Commander R. S. Barnaby, who is also head of the Soaring Society of America. In the construction of these gliders, the Navy Department has been most emphatic that they shall be built, insofar as possible, from non-strategic materials in order that as much aluminum as possible and other metals can be devoted to other purposes. The use of molded plywood for the manufacture of all types of civil and military aircraft is increasing with tremendous rapidity and it is expected that with the exception of the very heavy bombers and large commercial aircraft, planes of all types will be made completely of molded plywood. The wood is not only absolutely water-proof, mold-proof and insect-proof, but the bond between the plies is stronger than wood itself and, weight-for-weight, plywood is stronger than metal. Thermo-setting plastics, one of the two types employed, are heat hardening. The other type of

plastics is known as "thermo-plastics" and these can be molded or remolded. A plastic in itself lacks proper tensile strength. It is, however, hard and therefore will absorb high shear and impact loads. As an adhesive, it tenaciously grasps when used as a bond. Hence, plastic is suitable in a stressed and loaded structure only when a filler agent, such as cloth or wood, is used and thereby becomes a bonding agent supporting fibers of complex structures and transmitting a load from one to the other. Because of its favorable weight-strength ratio, wood is a practical filler for aircraft structures and, therefore, veneers can easily be used.

R. H. O.

Tie Dominates Rib in St. Georges Arch.—MAURICE N. QUADE. (*Engineering News-Record*, Vol. 128, No. 1.) The new highway bridge that carries the Du Pont Highway over the Chesapeake and Delaware Canal at St. Georges, Del., fourteen miles south of Wilmington, has a main span consisting of a 540 ft. tied arch of unusual design, its claim to distinction resting in the fact that the bending moments caused by partial live loads are resisted principally by the tension tie rather than the compression rib. Contrary to the usual tied arch designs, the tie consists of a deep box girder having approximately thirteen times the moment of inertia of the rib, which is shallow and corresponds quite closely to the proportions of a conventional top chord of a simple truss span of the same length and loading. In its action as a stiffening member, the tie girder acts for the arch rib in much the same manner as a stiffening girder or truss acts in providing rigidity for a suspension bridge. Although there appears to be a European precedent, it is believed that the St. Georges Bridge introduces a new type of bridge structure to American practice. The bridge, which also includes 3,669 ft. of plate girder spans about equally divided between the two approaches, replaces a lift span that was wrecked by a freight steamer. The four lanes of traffic which the new bridge provides remove a bottleneck in this dual highway that was caused by the 24 ft. roadway of the lift bridge. Delays to highway traffic and canal shipping due to the lift bridge are also eliminated by the 540 ft. high level arch span, which furnishes a 135 ft. vertical clearance over a 400 ft. width. The span has 15 panels 35 ft. 11½ in. in length. The arch ribs are straight between panel points, which lie on a parabola having a rise of 100 ft. The tie girders are slightly curved and conform to the vertical curve in the roadway, which is a parabola between tangents to the 5 per cent. approach grades at the ends of the span.

R. H. O.

Aluminum-Magnesium Alloys Resist Attack.—L. J. BENSON AND R. B. MEARS. (*Chemical and Metallurgical Engineering*, Vol. 49, No. 1.) Among the alloys that have come into prominence during the past few years are aluminum base alloys containing varying amounts of magnesium. These alloys not only possess the characteristics of lightness in weight inherent in both metals, but also exhibit in many cases marked resistance to the action of alkaline media. Recently, tests have been completed which throw considerable light on the resistance to chemicals. In tests conducted at 31 deg. C the rate of attack becomes appreciable only in concentrations of 0.1 per cent. and above of sodium hydroxide or sulphuric acid on high purity aluminum, high purity aluminum base alloys containing magnesium, and on certain aluminum-magnesium alloys of commercial purity. Aluminum-magnesium alloys containing 4 per cent. and more magnesium are equally or more resistant to the action of 0.1 and 1 per cent. solutions of sodium hydroxide than are alloys containing lesser amounts of magnesium. This effect was not evident in the 10 per cent. sodium hydroxide solution. Alloys containing 4 per cent. and more magnesium are less resistant to the action of 0.1, 1, and 10 per cent. sulphuric acid solutions than are alloys having lower magnesium contents. An addition of sodium dichromate to a 10 per cent. sulphuric acid solution accelerated the attack somewhat, while a similar addition to a sulphuric acid-sodium chloride solution served to produce a very material acceleration of attack.

R. H. O.

Practical Fire-Sensitivity of Liquid-Oxygen Explosives Treated with Fire Retardants.—This is the title of a report of investigations, Number 3605, by A. R. T. DENUES to the Bureau of Mines, Department of Interior. Dr. R. R. SAYERS, Director of the Bureau, stated, in connection with the work, that liquid-oxygen explosives—highly inflammable and subject to accidental ignition by matches, cigarettes and other common causes—have been rendered safer by a method of treatment with fire-retardant chemicals developed by the Bureau of Mines over a period of years. Further recent tests reveal that such explosives can be made virtually immune to many of the practical hazards of accidental ignition without impairing their usefulness. Explosives of the liquid-oxygen type are used chiefly for blasting in rock quarries and open pit coal mining operations, and for removing stumps in agricultural work. High inflammability and extreme sensitivity to dropping, jolting and other sudden movements are the characteristics that render them a

menace to life and property if handled carelessly. Although treated explosives will withstand most of the ordinary conditions of handling, the Bureau of Mines emphasizes the fact that certain inherent hazards remain, especially when large charges are exposed to extremely violent igniting agents. For this reason it is recommended that the usual safety precautions be exercised when handling treated explosives. Liquid-oxygen explosives are commonly made from a carbonaceous absorbent, and liquid oxygen of high purity. The fire-retardant treatment developed by the Bureau of Mines consists of spraying the absorbent with watery solutions of phosphoric acid before it is charged into the cartridge. For additional protection, the canvas wrappers in which packed cartridges are stored are soaked or sprayed with solutions of ammonium phosphate, ammonium chloride or phosphoric acid.

R. H. O.

Aeronautical Research.—The continuing need for research in this subject is well set forth in the twenty-seventh annual report of the National Advisory Committee for Aeronautics transmitted to the Congress by the President of the United States. It is shown that both fundamental and specialized research are necessary. The outstanding fighters of 1940–41—the British Spitfire and Hurricane airplanes and the German Messerschmitt 109F—had maximum speeds of the order of 360 miles per hour. The American aircraft program must provide new fighters for 1941–42 of much higher speed. A speed of 400 miles per hour and as much more as is practical is an obvious necessity. The factors involved include not only clean aerodynamic design, but the discovery of new principles and facts whose application in design leads to real improvements. It is not enough merely to increase the horse power and to smooth the surfaces. It was necessary to develop a new wing section of low-drag type, to obtain accurate data in a low turbulence wind tunnel of its lift and drag, to determine the effect of various types of flaps for increasing lift, and the action of normal and other lateral control devices. It was also essential to reëxamine the method of cowling and cooling both air-cooled and liquid-cooled engines at high air speeds. Special cowlings were required to handle the air needed to cool the engine, the oil radiator, the intercooler and, in the liquid-cooled type, the radiator. This work was based on theoretical analysis and proved in wind-tunnel and flight tests. With the exception of dive-bombing problems and problems incident to armament installations, practically all of the research of the Committee is directly applicable to civil types of aircraft. Improve-

ments in large two- and four-engine airplanes of the bombing type will undoubtedly be reflected in transport planes of tomorrow. New and improved engine installations, wing forms and propeller designs developed for military types will be important factors in increasing the speed and efficiency of future civil aircraft.

R. H. O.

Corn Yields Tartaric Acid by New Fermentation Process.—With imports of tartaric acid cut sharply by war, and with its price increased nearly 150 per cent., the United States Department of Agriculture is watching the results of research that indicate the possibility of converting corn into tartaric acid. Dr. O. E. May, Director of Northern Regional Research Laboratory at Peoria, Illinois, has reported that research workers of the Laboratory have developed an efficient and cheap means of producing from corn sugar an intermediate product, 5 ketogluconic acid, from which tartaric acid may be synthesized. The method worked out on laboratory scale will be tested in pilot plant equipment. The United States has a plentiful supply of corn sugar or glucose. The ketogluconic acid process has resulted from investigations conducted in the Fermentation Division of the Bureau of Agricultural Chemistry and Engineering. One of the early achievements of fermentation studies, another example of practical gains in this direction, was the manufacture of citric acid, using molds as the active micro-organisms. By means of the fermentation process, the United States—which had been relying mainly on European sources and paying up to $1.25 a pound—is now entirely self-sufficient with ample citric acid supplies selling at about 20 cents a pound, and with a surplus for export. United States production of citric acid, Doctor May says, runs close to 20,000,000 pounds a year.

R. H. O.

Jute Shortage Widespread.—United States farmers are not alone in feeling the shortage of jute from India for making burlap bags. Brazil and Ecuador also need jute, particularly for coffee bags, of which Brazil uses about 15 million a year. Both countries are now looking for native fibers to replace jute, the U. S. Department of Agriculture reports. In this country cotton is urged for bagging, and bagging is also a good use for surplus cotton. But now while defense orders have first call on cotton bagging fabrics, there has been some interest in the possibility of getting South American substitutes for jute. The jute shortage is likely to continue since India, seeing no probable relief of the shipping shortage,

has cut its jute acreage in half. Eventually the United States may buy several South American fibers as substitutes for jute, but not for some time to come, the Office of Foreign Agricultural Relations says. Brazil and Ecuador will need them at home. Brazil has at least 5 promising wild fibers out of about 15 fiber-yielding plants. These five are known as paco-paco, juta indiana, malva veludo, guaxima, and papoula de Sao Francisco. Guaxima is said to exceed 3 feet in length and to produce a good yield per acre. It is used in mixture with jute, as is papoula de Sao Francisco. With additional acreage in cultivation one group of mills hopes to become independent of jute, and to export finished bagging. In Ecuador the wild fourcroya plant yields cabuya fiber, which natives use for making bags and bagging, ropes, belts, and soles for sandals. At present there are only two cabuya plantations. Increased production would depend on demand. Uruguay has at least 8 fiber plants but landowners find it more profitable to specialize on meat and wool.

R. H. O.